Transactions of American Society for Steel Treating

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SPECIAL FEATURES

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4600 Prospect Avenue

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II — Cleveland, June 1922 — No. 9

HOTEL RESERVATIONS FOR DETROIT CONVENTION

Statler Hotel, Convention Headquarters

DETROIT has promised to provide all of our members and guests with excellent accommodations as far as hotels are concerned. Through the efforts of D. J. Crowley, 832 Dime Bank Building, Detroit, Chairman of the Hotel Committee, a list of hotels is given below with their rates for single and double rooms as well as the number of reservations each hotel will accept. The Statler Hotel will be the official headquarters. All persons in attendance at Detroit will make their own hotel reservation direct with the managers and it is advisable that the members take the following precaution: When making reservations, state that you are attending the International Steel Exposition and Convention of the American Society for Steel Treating, give the date of arrival, kind of room desired and the price you wish to pay. Request the hotel manager to answer your letter repeating the reservation, then take the letter with you to Detroit and present it when you register. This precaution taken now may avoid serious difficulty during the rush of the Convention. It is recommended that reservations be made immediately.

The list of hotels follow:

Lincoln Hotel

Rate Without Bath	Rate With Bath
Single $1.25, $1.50, $1.75, $2.00	Single 6 showers and tubs on each floor
Double $2.50, $3.00 (2 men)	Double no private baths

Will accommodate 75

Remarks: Large lobby. Good cafeteria.

Hotel Fort Shelby

Rate Without Bath	Rate With Bath
Single $2.00	Single $3.00, $3.50, $4 00, $5 00
Double $3.00	Double $5.00, $6.00, $7.00

Will accommodate 50 to 100

Cadillac Hotel

Rate Without Bath	Rate With Bath
Single 2.00, $2.50	Single $2.50, $3.00, $3.50, $4.00
Double $3.00, $3.50, $4.00	Double $4.00, $5.00, $6.00, $7.00

Will accommodate 500

Charlevoix Hotel

Rate With Bath
Single $3.00, $3.50, $4.00
Double $5.00, $6.00

Two-Room Suites............$7.00
Three-Room Suites $8.25
Four-Room Suites $9.00

Number of persons with notice—100

Hotel Wolverine

Rate With Bath
Single $2.50, $3.00, $3.50, $4.00, $4.50, $5.00, $6.00
Double $4.50, $5.00, $5.50, $6.00, $6.50, $7.00, $8.00
Will accommodate 300

Hotel Norton

Rate Without Bath
Single $2.00 to $2.25
Double $4.00

Rate With Bath
Single $2.50 to $3.00
Double $4.50 to $5.50

Will accommodate 100

Hotel Normandie

Rate Without Bath
Single $1.50 to $2.00
Double $2.50 to $3.00

Rate With Bath
Single $2.50 to $3.00
Double $3.50 to $4.00

Will accommodate 100

Madison-Lenox

Rate Without Bath
Single $2.00
Double $3.00

Rate With Bath
Single $2.50, $3.00
Double $3.50, $4.00

Will accommodate 100 or more

Library Park Hotel

Rate Without Bath
Single $1.25 to $2.00
Double $2.00 to $3.00

Rate With Bath
Single $3.00
Double $4.00

Will accommodate 50

Hotel Stevenson

Rate With Bath
Single $2.50
Double $3.50
Will accommodate 50

Hotel Statler

Rate With Shower
Single $3.00 to $3.50
Double $5.00 to $5.50

Rate With Bath
Single $4.00 to $ 8.00
Double $6.00 to $10.00

Will accommodate—400 rooms to take care of 600 to 800 people

Hotel Tuller

Rate With Bath
Single $2.50
Double $4.50
Will accommodate 300

Hotel Griswold

Rate Without Bath
Single $2.00
Double $3.00

Rate With Bath
Single $2.50, $3.00, $3.50
Double $4.00, $5.00, $6.00

Will accommodate 125

Hotel Addison

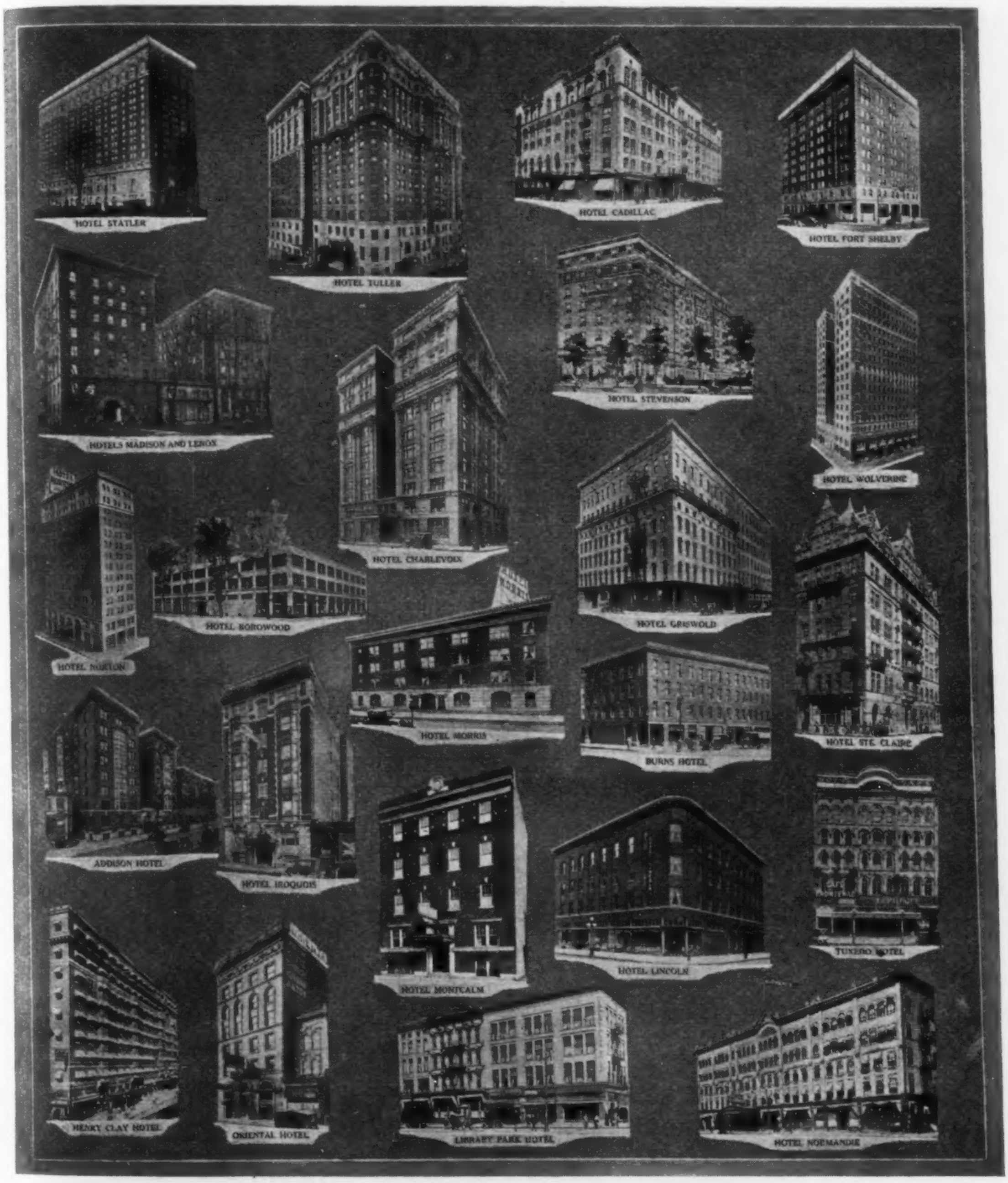
Rate Without Bath
Single $1.50
Double $3.00

Rate With Bath
Single $2.50
Double $4.00

Will accommodate 250

DETROIT CONVENTION

We are pleased to announce that the railroads of the country through the Central Passenger Association have granted fare and one-half round trip for members of the Society and their dependants attending the International Steel Exposition and Conventions of the American Society for



Detroit Hotels

Steel Treating and the American Drop Forging Institute at Detroit, October 2nd and 7th.

There are certain restrictions placed on the purchase of these tickets inasmuch as an identification certificate must be presented to the ticket agent before one may purchase round trip tickets at the reduced rate. This iden-

tification certificate will be mailed to members of the Society before the time of the Convention. Reduced rates were offered as an experiment last year by the railroads to those attending the Indianapolis Convention. Because of the large number using the plan the special rate was granted again this year. The granting of this rate means the saving of thousands of dollars to the members of the Society as wives and other members of a family may also have the advantage of this reduction.

The American Drop Forging Institute has accepted the invitation to hold their Annual Convention at Detroit concurrently with that of the American Society for Steel Treating. Certain portions of the program have been set aside for the use of the Forging Industry, and many members of the American Drop Forge Supply Association will have their products on exhibition. The program of the two conventions will be worked out in such a manner as not to conflict, but the entertainment features, as well as one or two of the sessions will be common to both the organizations.

The exhibition will be the largest the Society has ever had. The main exhibition hall 500 x 30 feet has practically all been reserved and additional floor space will have to be opened up to take care of the many exhibitors who wish to be present.

EDITOR'S GREETINGS

SINCERE and hearty greetings and felicitations are extended to all of our members and readers by your recently appointed editor. In laying the course and guiding the TRANSACTIONS to a more propitious and helpful position than it now holds, we feel dependent to a greater or less degree upon all of our readers. At the present time the TRANSACTIONS of the Society holds a very enviable position in the technical literature and is covering a field of endeavor which up to a short time ago had been somewhat neglected. In our desire to increase the value of our publication we have worked out some very definite lines of procedure in carrying on and enlarging the work of the TRANSACTIONS and as these new features are brought forth, we want your expressions on their value in making our official organ more valuable to all.

Your co-operation is indeed essential; it is absolutely imperative that we have it. Without it, the work of TRANSACTIONS will probably not be all that you desired of it. Your assistance, your words of confidence, your criticisms and helpful discussions are quite needed and earnestly solicited. Do not hesitate to express yourself, either when you favor or disapprove of any action which has been taken or which may be under consideration. Only through knowledge of the desire of the membership can we be sure of pleasing the majority. Let us have your ideas which you believe will improve the Society's publication. In the interest of greater service to all, it is hoped that you will assist in making the TRANSACTIONS what you would like to see it.

With this issue begins a change in the character of the binding of the TRANSACTIONS. This change is from the saddle stitch to the side stitch, which permits of considerable more flexibility in the make up of the book and lends itself more admirably to binding when the volume is complete.

DR. HENRY MARION HOWE
1848 - 1922

HENRY MARION HOWE, premier American scientist in the realm of iron and steel metallurgy, died on Sunday, May 14, 1922, at his home in Bedford Hills., N. Y. from an illness which he has suffered for many months. He was born March 2, 1848 at Boston, the son of Dr. Samuel G. Howe and Julia Ward Howe. Both parents were prominent in public activities; his father for his philanthrophy and interest in the welfare of the blind and feeble minded, and his distinguished service in the Grecian war for independence in the early 19th century; his mother for her leadership in the abolition of slavery, her efforts in securing of suffrage for women in the United States. From his mother, who was author of "The Battle Hymn of the Republic" he inherited a marked versatility in writing and had a wonderful ability of presiding over and directing public meetings. From his father, who was always active in medical research he inherited that extraordinary quality of keen vision and power of observation which is so essential in investigative endeavor and research.

His early education in the Boston Latin School was followed by his study in Harvard College from which he was graduated in the year 1869, with the degree of A. B. and in 1872 received the degree of M. A. In 1871 he received the degree of B. S. from Massachusetts Institute of Technology where he specialized in work in the department of Mining and Metallurgy.

Later he received the Honorary degree of LL.D. 1905 from Harvard University.

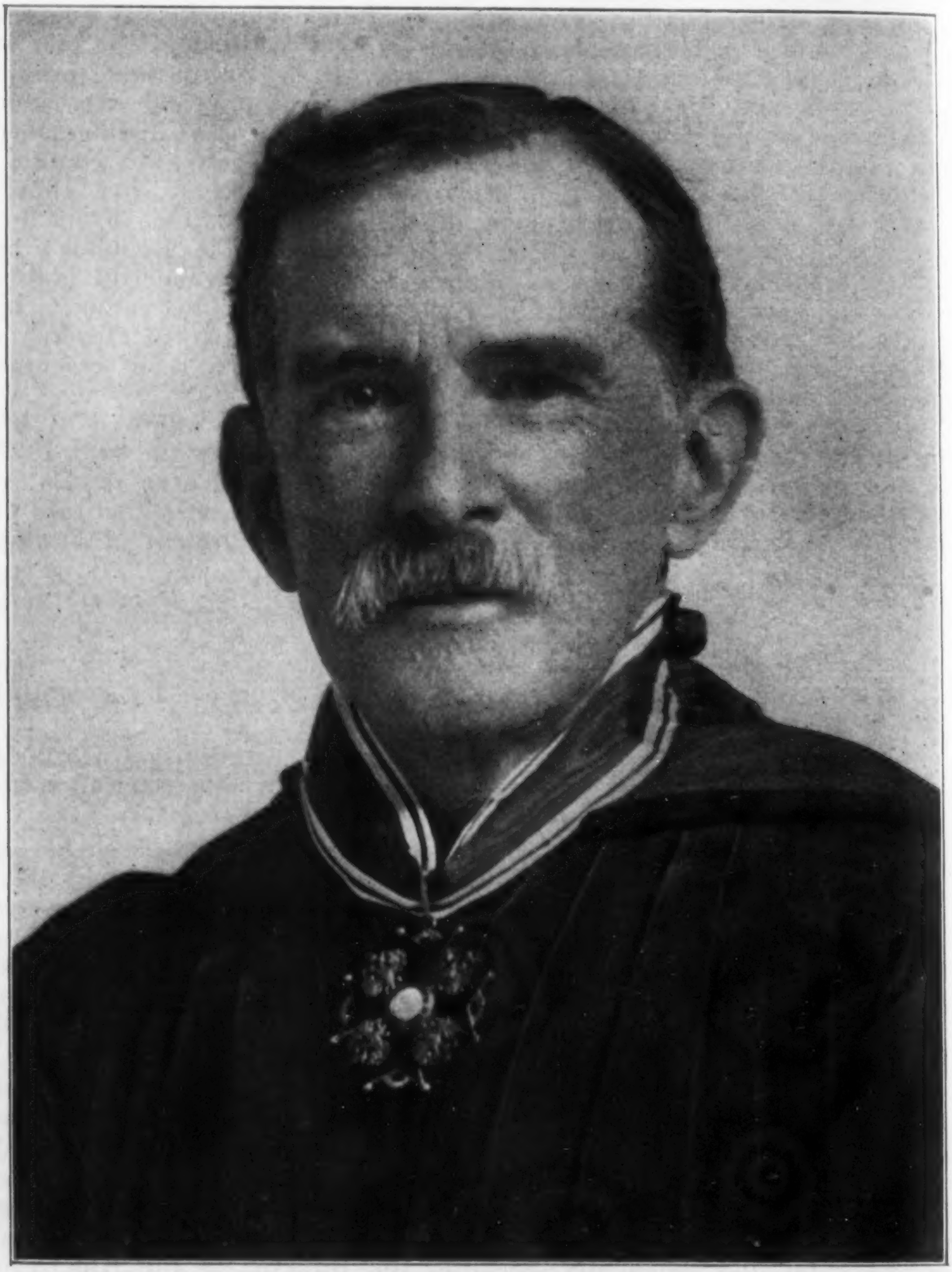
On April 9, 1874 he married Miss Fannie Gay of Troy, N. Y. who survives him. She has always been a devoted helper in his scientific service to the world.

Following his academic work he engaged in metallurigal work at Pittsburgh and Troy where he early gained an enviable reputation as an investigator and keen observer.

In 1880 he designed and built the works of the Oxford Nickel & Copper Company, at Capelton and Eustic, Quebec. From 1883 to 1897 he acted as consulting metallurgist and also lectured at Massachusetts Institute of Technology. It was in 1890 that he introduced the manufacture of Hadfield manganese steel in the United States. He became professor of metallurgy at Columbia in 1897 and in 1913 professor emeritus. He distinguished himself by his indefatigable research and investigation.

Prof. Howe published his first book, "Copper Smelting" in 1885, and in 1891 "The Metallurgy of Steel" which was translated into French. In 1902 "Metallurgical Laboratory Notes" was published and translated into French and in 1903 "Iron, Steel and Other Alloys," translated in Russian. He contributed more than 300 professional papers and was a foremost leader in the science of metallography. Many honors were conferred upon him which are given in the Bulletin of the American Institute of Mining Engineers for July 1913, among which we might mention were the Bessemer Medal, the Gold Medal of the Society for Encouragement of National Industry of France, the Gold Medal of the German Society for Promotion of Technical Industry, the Knighthood of the Order of St. Stanislas of Russia and the Elliott Cresson Gold

Medal of the Franklin Institute, Philadelphia. He was a member of many foreign societies and orders. He was a non-resident Fellow of the American Philosophical society and American Academy of Arts and



Dr. Henry Marion Howe

Sciences, honorary member of the American Society for Steel Treating, American Iron and Steel Institute and many others.

Dr. Howe was an expert in litigation on iron and steel. His chief

contribution to the scientific world, however, was his development of the science of metallography which was the result of his great powers of observation and deduction. His ability for correlating and interpreting each discovery and investigation by others and supplementing them by investigations of his own resulted in the establishment of a new science, dealing with the constitution of iron and steel.

During the World war he was chairman of the engineering division of the National Research Council which he resigned in 1919 and remained as honorary chairman until his death.

The death of Dr. Howe makes an irretrievable loss to the world of metallurgical science.

REPORT OF NOMINATING COMMITTEE

To the Secretary of the American Society for Steel Treating:

The National Nominating Committee, meeting accordingly to the Constitution of the American Society for Steel Treating, selected as unanimous choice of those present the following men for nominees for office:

President—T. D. Lynch, Pittsburgh, Pa.
Second Vice President—W. S. Bidle, Cleveland, Ohio.
Secretary—W. H. Eisenman, Cleveland, Ohio.
Director—Samuel M. Havens, Harvey, Ill.

According to Section 10 of Article VII of the By-Laws, we are enclosing the written consent of these gentlemen to their nomination.

Yours very truly,
NATIONAL NOMINATING COMMITTEE,
American Society for Steel Treating.
(Signed)
C. S. MOODY,
H. C. GOODWILL,
CARL SCHUMANN,
D. W. McDOWELL, Chairman.

BIOGRAPHY OF NOMINEES FOR OFFICES IN THE NATIONAL SOCIETY

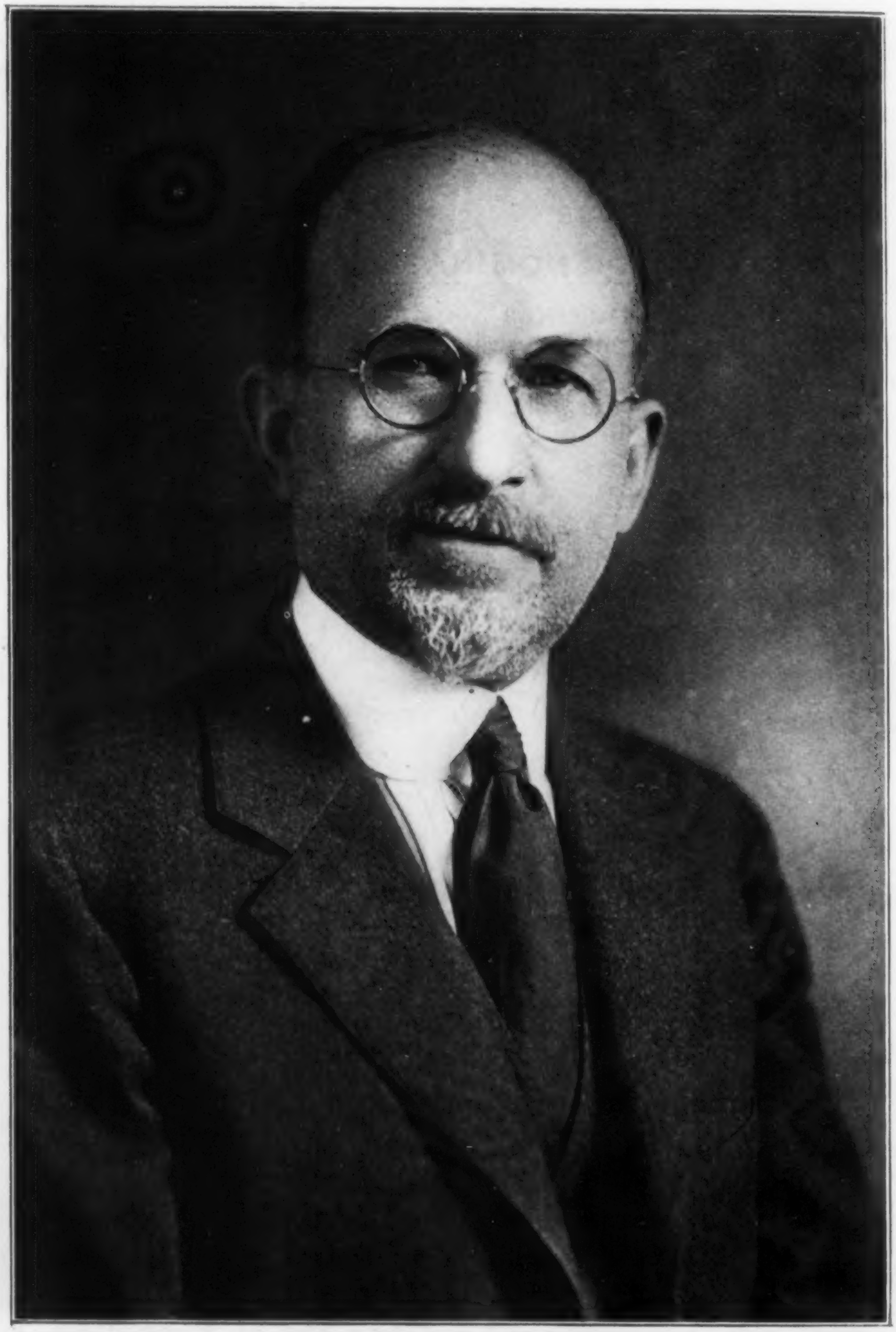
Tillman Davis Lynch

Nominee for National President of the Society

BORN in Harrison County, West Virginia, in 1867, of pure American descent. Spent his boyhood on a farm learning how to make things grow. Attended a district country school where at times as many as sixty scholars were accommodated in one large room. Took preparatory work at the Academy of Buckhannon, W. Va., and from there went to West Virginia University at Morgantown, W. Va., graduating in 1891 with the degree of C. E.

In order to procure funds to meet the expenses at the University, all vacations, week ends, any many evenings, were devoted to remunerative employment, such as surveying and making a plot of Morgantown, W. Va., surveying in the oil and gas fields, laying out a railroad location through Fairmont, W. Va., and spending one summer on the maintenance of way, Maryland Division, Pennsylvania Railroad Company.

After graduation, joined the contracting and inspecting engineering firm of G. W. G. Ferris & Company, with offices at Pittsburgh, Chicago,



Tillman Davis Lynch

Nominee for National President of the Society.

and New York. From 1891 to 1897 on inspection at mill, foundry, shop and field erection, and the last two years in charge of the Chicago office.

With the United States Navy, Bureau of Steam Engineering, 1897 to 1899, covering the period of the Spanish War,—on inspection work at foundry and mill, armor plate, structural materials, boiler tubes, ferrous and non-ferrous castings, including the manufacture and treatment of hull and engine steel castings.

With the Westinghouse Electric and Manufacturing Company 1899 to date—on the general subject of materials, treatments and their applications, including such sub-divisions as inspector of materials, engineer of tests, section engineer in charge of manufacturing processes, materials specifications, metallurgical engineering on both ferrous and non-ferrous metals, materials in design and the application of research work to commercial use.

Member of the American Society for Testing Materials, active on ten of its main committees and eight additional sub-committees, covering steel, iron, non-ferrous alloys, standardizing of tests, heat treatment, effects of phosphorus and sulphur on steel, and corrosion of steel.

Member of the Engineering Society of Western Pennsylvania.

Member of the American Society for Steel Treating. Was vice president during the first year of this Society's organization and active in formulating policies of the Society. Chairman of its standards committee since its organization and active in the affairs of the Pittsburgh Chapter.

Several technical papers have been presented to the following societies and to the press:

1908—Vol. VIII,—American Society for Testing Materials.
"The Use of the Extensometer in Commercial Work."

1910—Vol. XXVI,—Engineering Society of Western Pennsylvania.
"Material Economics."

1913—Vol. XIII,—American Society for Testing Materials.
"A Study of Bearing Metals and Methods of Testing."

1915—Vol. XV,—American Society for Testing Materials.
"Elastic Limit."

1916—Vol. XVI,—American Society for Testing Materials.
"Relation Between Yield Point and Proportional Limit."

1916—Electric Journal—"Bakelite Micarta—Gears and Pinions."

1919—Electric Journal—"Manufacture of High Explosive Shells."

1919—(American Society for Steel Treating)
(Engineering Society of Western Pennsylvania)
"Notes on Heat Treatment of Steel."

1919—American Institute of Mining and Metallurgical Engineers,
"Cooling Properties of Technical Liquids."

1920—Iron and Steel Electrical Engineers.
"Babbits and Babbitting."

1921—American Society for Steel Treating, Indianapolis Convention.
"Tests Showing the Effect of High Temperatures on Malleable Iron."

1922—Chairman of Symposium Committee on "Impact Testing," American Society for Testing Materials for the convention to be held at Atlantic City, June, 1922.

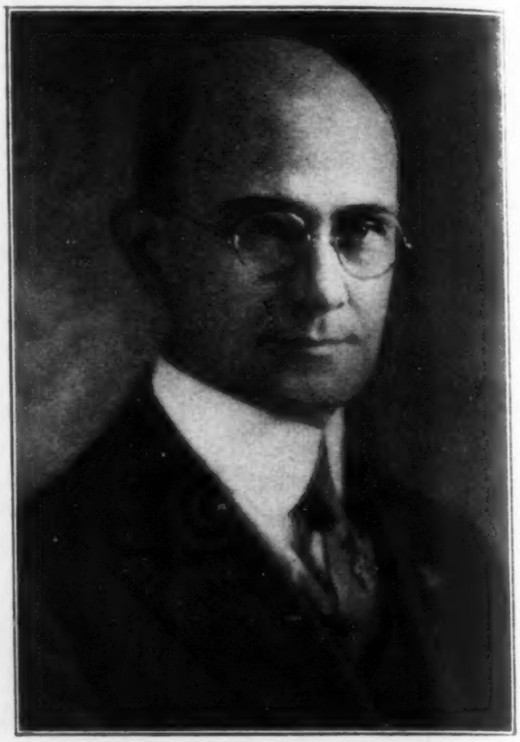
W. S. Bidle

Nominated Second Vice President of the Society

Born Cleveland, Ohio, June 26, 1872. Graduate of Cleveland Public Schools.

Graduated from Case School of Applied Science in 1893, receiving degree of B. S. In 1898 received degree of M. A. from same college. Member of Sigma Xi and Tau Beta Pi fraternities.

From 1896 to 1912 was manager turn-buckle department of Cleveland City Forge & Iron Company. From 1913 to date, President of W. S. Bidle Company, Commercial Steel Treating, Cold Drawing and Turning.



W. S. Bidle
Nominee for Second Vice President of the Society

W. H. Eisenman
Nominee for National Secretary of the Society

W. H. Eisenman

Renominated National Secretary of the Society

Graduate of Kenyon College, degree Ph. B. Two years post graduate work at Leland Stanford, Jr. University, specializing in law and sciences, receiving an M. A. degree for special research work in chemistry. In addition completed post-graduate study at Morningside College and Ohio State University.

Was successively principal of high school; instructor chemistry Racine College; head of chemistry department of large high school and superintendent of schools.

Finally and at present National Secretary of the American Society for Steel Treating.

Samuel M. Havens

Nominated National Director for two years.

Graduated from the University of Rochester with the degree of A. B., and three years later from the law school of Columbia University with the degree of L.L.B.

Practiced law in New York City for five years, after which he moved to Rochester, N. Y., where he practiced for 10 years. During that time he was a member successively of the two leading law firms of that city. During this time Mr. Havens gave his attention primarily to corporations and earned an enviable reputation as a successful corporation attorney.

Mr. Havens has been as successful in business as in the legal profession. In 1917 he became secretary of the Ingalls-Shepard Forging Company of Harvey, Illinois and continued in that capacity until 1920 when he was made Assistant Treasurer and Manager of the Ingalls-Shepard Division, Wyman Gordon Company, in which position he has continued.

S. M. Havens

Nominee for National Director of the Society

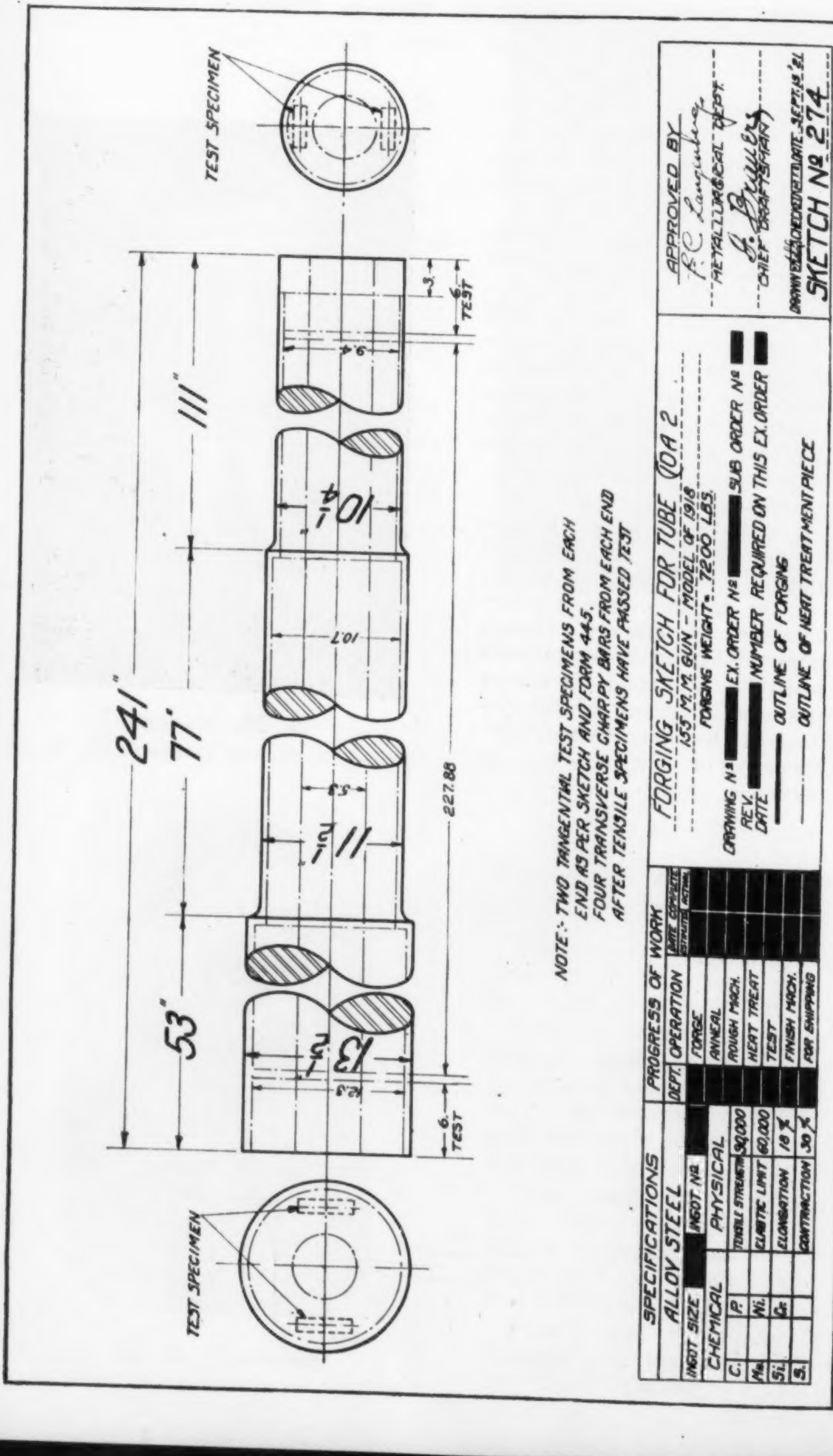


Fig. 1—A typical forging sketch giving the specifications required as well as the character and location of test specimens

PLANNING AND ROUTING OF FORGING AND HEAT TREATMENT WORK AT WATERTOWN ARSENAL

By F. C. Langenberg

AS THE Watertown Arsenal, both in war time and under normal conditions, is called upon to produce a great variety of forgings, having widely different physical characteristics, it has been necessary to evolve a very close system of control.

Since the signing of the armistice, considerable development work has been done at Watertown Arsenal, including the production of gun forgings having high physical properties, and also several experimental gun mounts. Such construction of experimental material means, in general, that only one forging or casting of a particular type is necessary. If all operations are not very carefully planned, rejections under such conditions will be exceedingly high. Therefore, the author will attempt to outline the method in vogue at Watertown Arsenal for the planning and routing of forging and heat treatment work.

The metallurgical division of the Watertown Arsenal reports directly to the commanding officer, the laboratories of the arsenal coming under the control of the metallurgical division. In order to illustrate the planning system, a 155-millimeter gun tube forging has been selected as a typical example.

Assuming that an order has been received for this forging, the engineering division issues, in addition to the regular drawings, a forging sketch, Fig. 1, which gives the specifications required, as well as the character of the test specimens and location of same. On this forging sketch, the heavy lines indicate the forging dimensions, whereas the light lines indicate the heat treatment dimensions or, in other words, the dimensions to which the tube is to be machined prior to heat treatment. The physical properties desired are shown in the column at the left of the drawing, and in cases where the production has been standardized, the chemical composition is also shown. Other shop information is placed on the forging sketch, such as the drawing and expenditure order number, as well as the sub order applying to the particular job in question.

As in some cases the forging cannot be heat treated when rough machined in accordance with the rough machine drawings issued by the ordnance department without serious danger of cracking, the forging sketch will, as indicated above, show the heat treatment size or, in other words, the dimensions to which the piece is to be machined prior to heat treatment. It is the function of the metallurgical division to furnish to the engineering division the necessary information regarding test specimens, dimensions, etc., so that it can issue the forging sketch containing the necessary information.

After the necessary drawings and expenditure orders have been issued by the engineering division, it is then the function of the planning division, under the works manager of the arsenal, to plan and route the work through the various shops. So that the work can be planned economically, the metallurgical division furnishes to the planning room the necessary information in regard to the size and weight of ingots which will be required in order to secure the proper reduction of area and pro-

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A paper presented at the Indianapoils Convention. The author, F. C. Langenberg, is metallurgist, Watertown Arsenal, Watertown, Mass.

per discard, and if ingots of the proper composition are not in stock, the necessary information is furnished so that the proper order can be placed with the foundry.

Very close co-operation is maintained between the metallurgical division and the foundry, and this is accomplished by calling into conference various members of the foundry personnel before final decisions are arrived at relative to any particular problem at hand. The metallurgical division maintains very careful records of the melting and pouring practice and makes, in addition, a very careful ingot inspection before shipment is made to the forge shop. When an ingot is received in the forge

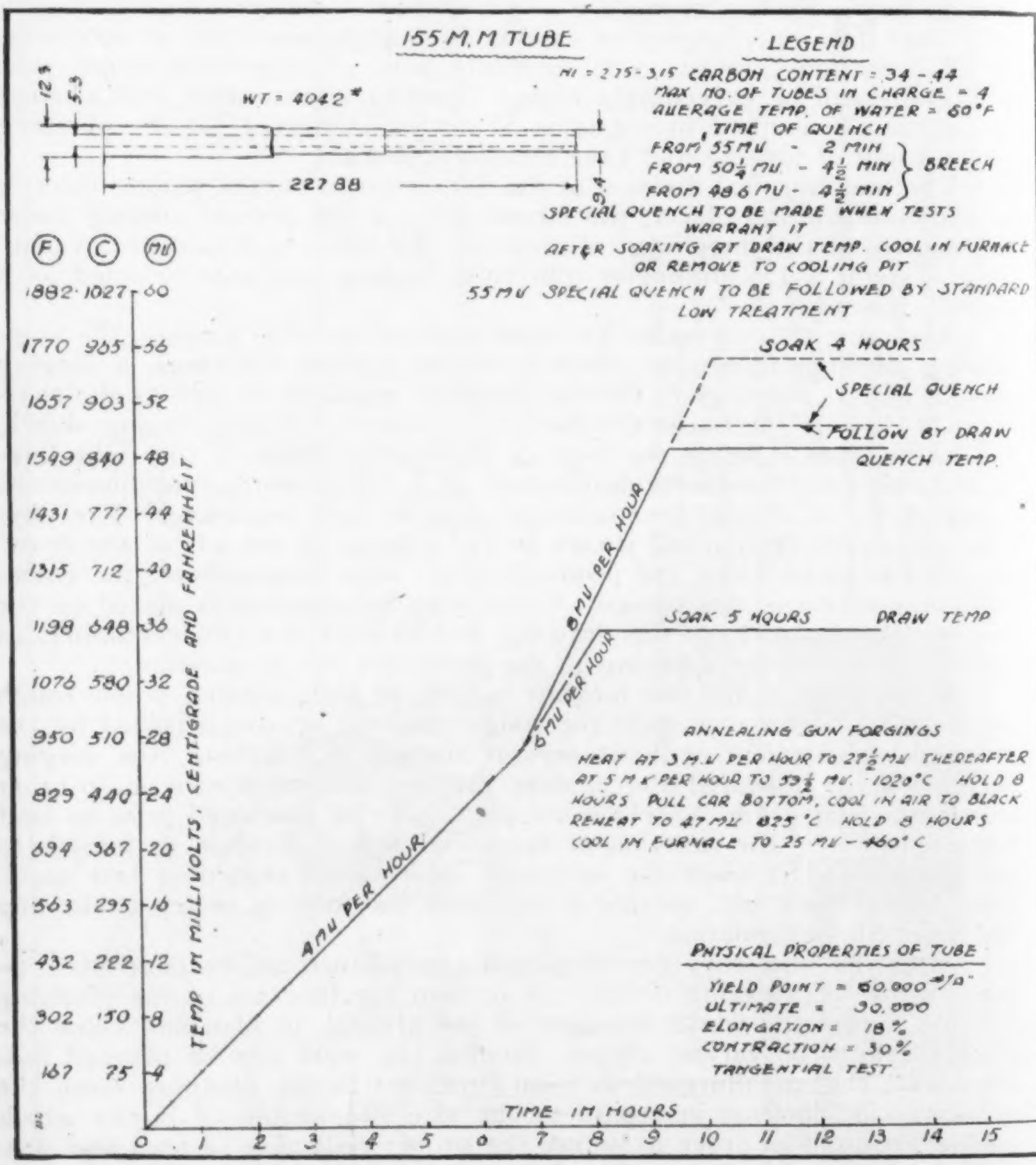


Fig. 2—Heat treatment temperature curve for gun forgings as issued to the heat treating shop

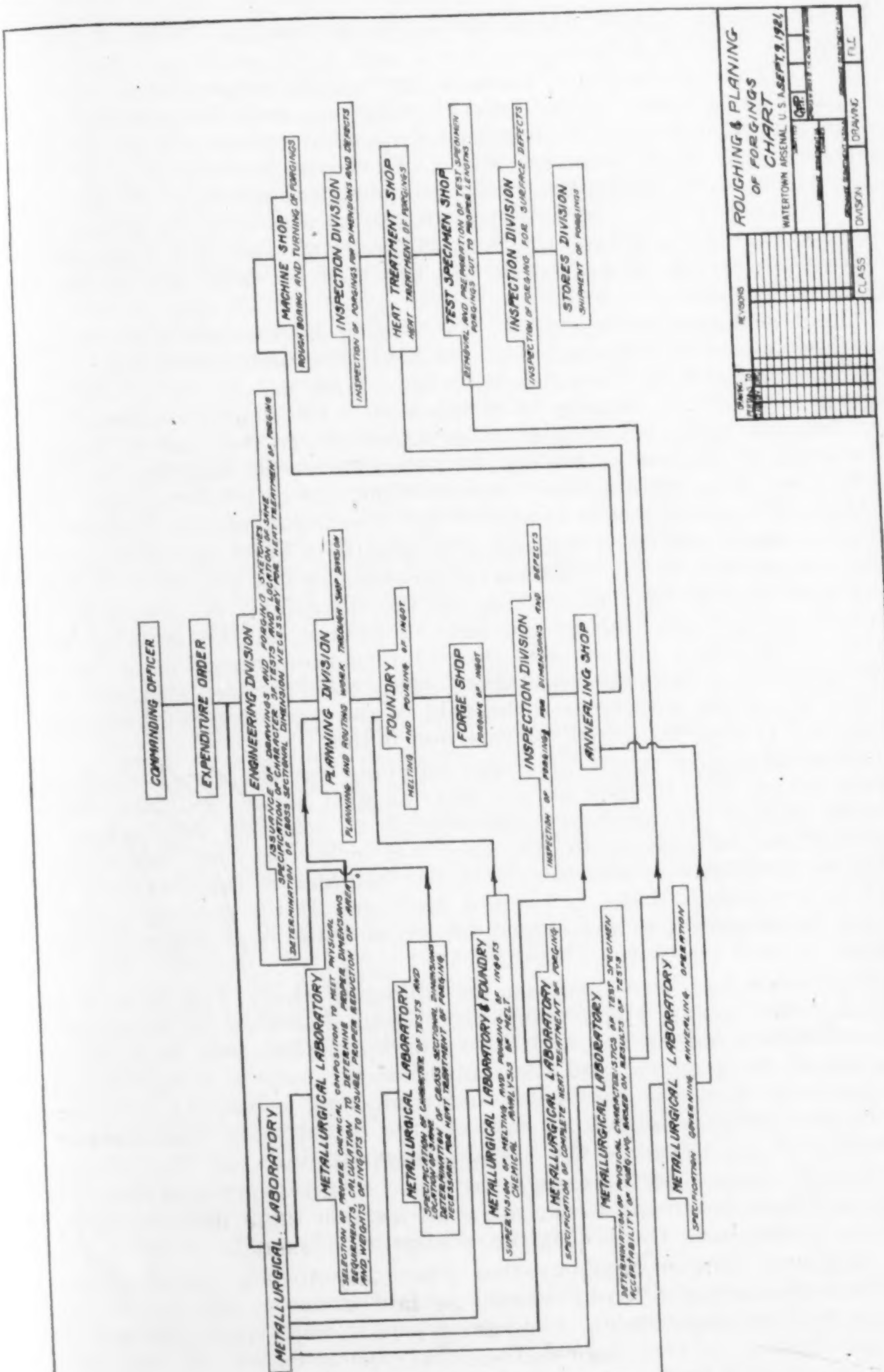


Fig. 3—Chart showing the various steps through which work must pass at the Watertown Arsenal

shop this division already has available the necessary sketches so that it can proceed without delay.

As soon as the forging is made, a very careful inspection is made by the inspection division of the arsenal, which is entirely independent of any metallurgical inspection, and this inspection covers the examination of the forging both as to dimensions and for any physical defects. Any defects are reported promptly to the metallurgical division. If the forging is satisfactory it is then shipped to the annealing shop, which shop has, prior to the receipt of the forging, received full and complete instructions as to the temperatures and times to be employed in the annealing operation.

After the annealing operation, the forging is transferred to the machine shop, where it is machined to the heat treatment dimensions. It is again inspected by the inspection division, and passed on to the heat treatment shop if the forging is satisfactory. The heat treatment shop, which has also received complete instructions as to the rate of heating, time of soaking, method of cooling, etc., then treats the forging, and after treatment removes the necessary test specimen as called for in the forging sketch, a copy of which is also in the possession of this division.

Fig. 2 shows the heat treatment instructions as they are issued to the heat treatment shop. The curve furnished gives the time of heating, as well as the time of soaking at the quenching temperature. It also gives the rate of heating and time of soaking at the drawing temperature. The curve shown also gives information regarding a special treatment which is applied when this forging fails to pass the first test. The time which the forging is to be held in the quenching medium from each quench is also furnished on this instruction chart.

The metallurgical laboratory, after carrying out the necessary physical tests, which may include impact tests as well as the standard tensile test, then makes the necessary decision as to whether the forging is satisfactory for submission to the inspector in its present condition or whether re-treatment is necessary. If re-treatment is necessary, no instructions are issued to the inspection division. If the forging is satisfactory it is passed on to the inspection division for final inspection and shipment.

The attempt has been made on the following chart, Fig. 3, to show graphically the various steps which have been described in this paper. The metallurgical laboratory, with its various functions, has been shown on the left of the drawing, and the routing of the forging to the various shops has been shown in the center and right-hand columns. The lines from the metallurgical laboratory indicate the instructions, and character of same, which are issued to the various shop divisions.

Although many objections might be found to this method of handling forging and heat treatment work, there are certain quite definite advantages which have been realized at the Watertown Arsenal.

It is a very human tendency that when any trouble occurs at the heat treatment shop the blame should be laid either to the forge shop or to the melting department; likewise, when trouble is encountered in the forge shop it is very logical that the superintendent of this shop ascribes the trouble to the melting department. When all of the operations are followed carefully by another division this tendency to pass the blame along is quite materially overcome, and the very frequent informal

conferences called by the metallurgical division have resulted in the various shop superintendents and foremen feeling that they are an essential part of any experimental program.

In the selection of the weight and cross section of a given ingot, as well as in the preparing of the forging sketch, the superintendent of the forge shop has been consulted, and as the final decision is one in which he has concurred, it is quite natural that he will make every effort to see that the job works out in a satisfactory manner.

The objection has sometimes been raised to the system employed that initiative is removed from the superintendent of a given shop who is responsible, and placed in the hands of another division. The actual working out of the system, however, does not indicate that this is the case. In the heat treating department, for instance, the superintendent is responsible for the conduct of his shop and is, furthermore, responsible that any treatment operation be carried out strictly in accordance with the instructions which he has received. If a forging fails to pass test and the treatments have been carried out as prescribed, the superintendent of the shop is not responsible for the difficulty, as the failure was due to reasons beyond his control. In other words, this system makes it quite possible to fix definitely the responsibilities of the various shop superintendents, and it has been the experience of this arsenal that all of them are in hearty accord with the system, as they know at all times what is required of them.

Discussion of Dr. Langenberg's Paper

MEMBER: Who determines the temperatures that the material is to be run at in any of the treatments that are conducted? You say the superintendent doesn't specify any particular temperatures.

DR. LANGENBERG: The temperatures are all given by the metallurgical division. Complete details are furnished by the metallurgical division, not only the temperatures, but the rates of heating, time of soaking, etc.

MEMBER: Isn't there a special chart of some kind issued by the engineering division that gives the physical properties desired or the treatment that is to be used?

DR. LANGENBERG: The physical properties are shown on the forging sketch, they are also shown on the heat treatment drawing.

MEMBER: Then it is entirely up to the metallurgical division to furnish the material according to their own ideas regarding the strength?

DR. LANGENBERG: No, this is not in our province. The designer has laid that out on the original drawings. We simply take the drawings that are furnished to us. We put down the physical properties and then we select the composition, the treatment, etc., which will, in our best judgment, get the physical properties which are needed.

MR. McINERNEY: Are any tests conducted after annealing or forging, before the pieces are sent to the shop to be machined?

DR. LANGENBERG: In a good many pieces we do conduct tests. On a number of forgings it has been necessary to determine whether our anneal is entirely satisfactory. We find that that can be accomplished by taking a test bar in the annealed state, and then make a microscopical examination from the test bar. That applies more particularly

to those forgings which require a very high physical property and which are of heavy section, where especial annealing has been given, but as a standard practice we wouldn't take tests after the annealing operation.

MR. McINERNEY: You don't follow that up as a rule, then?

DR. LANGENBERG: No, only on very special occasions do we do that.

MR. McINERNEY: Do you prescribe a separate temperature for each individual piece?

DR. LANGENBERG: The fact is that our various physical properties are met with several more or less standard compositions. We have 3.5 per cent nickel steel; in that case the temperature would be standard and only the time would be varied in accordance with the section.

MR. McINERNEY: What is it, open-hearth steel you have there?

DR. LANGENBERG: Open-hearth and electric.

PROFESSOR SAUVEUR: Have your methods resulted in any change in the quality of forgings, and in what direction?

DR. LANGENBERG: In my opinion they have resulted in securing better forgings. I think the four to one specification which was originally held to was more or less a relic than anything else, and some of the best forgings which were manufactured during the war were made with a reduction of area of 1½ to 1, and better physical results were obtained. It is very seldom that we exceed the 2 to 1 ratio at the present time. In fact, we try to keep within that. The trouble comes, however, in making a long tube; to maintain the 2 to 1 reduction in area, a very long ingot is required in relation to its diameter, which results in very serious losses in the foundry.

MR. THUM: May I ask whether you forge under a hammer or a press?

DR. LANGENBERG: All of the major forgings are made under a press; smaller breech blocks and parts of that sort are made with the hammer.

MR. THUM: What is your opinion as to the relative value of the two? Would it be safe, in other words, to reduce the forging ratio under the hammer to 1½ to 1, or 2 to 1, where it might not be safe under the press?

DR. LANGENBERG: We have never had any direct experience on that ourselves, but I know of one company that made a number of forgings, finished them under the hammer, and in that case the reduction in area was very high, much over 4 to 1, and they secured very good results. I believe they secured better results than if this same reduction had been obtained under the press.

MEMBER: I would like to ask Dr. Langenberg whether he doesn't think it is easier to meet the required physical properties, which I believe are 18 per cent elongation and 30 per cent reduction of area, with the 2 to 1 forging reduction on the ingot than it was when the specified reduction was 4 to 1? In other words, if it is not easier to meet the specification with the smaller reduction?

DR. LANGENBERG: I don't think there is any question about it. I think we can meet that specification much easier with the smaller reduction. In other words, you will come more nearly having a uniform physical property in all directions with a 2 to 1 reduction than you will with a 4 to 1, other conditions being equal.

EFFECT OF HEAT TREATMENT ON MECHANICAL PROPERTIES OF A CARBON-MOLYBDENUM AND A CHROMIUM-MOLYBDENUM STEEL

By H. J. French

WHILE the use of molybdenum as an alloying element in steels is not of recent origin, widespread attention has been given recently to the benefits derived from the addition of relatively small proportions of this element to various carbon and alloy structural steels which are generally subjected to heat treatment prior to use and usually referred to as automobile steels. More precisely, the addition of about 0.25 to 1.0 per cent of molybdenum to carbon, chromium, nickel, nickel-chromium and chromium-vanadium steels of the types widely used in automotive work is claimed to confer on the quenched and tempered alloys increased strength without material decrease in ductility. In some cases, as for example in nickel and chromium steels, this is accomplished without increasing the total proportion of alloying elements by replacing a portion of the nickel or chromium with molybdenum.

The general advantages observed, in so far as the heat treatment of molybdenum steels is concerned, have been summarized by Schmid[1] as follows:

"The outstanding features relative to the heat-treatment of molybdenum steels are the extremely wide quenching ranges available for practical heat treatment; the excellent penetrative effect of such treatment on large sizes; and the broad drawing range causing but slight modification in physical properties, this due to the retarded dissociation and reversion to normal state upon heat application after quenching."

Despite the recent publication of many data relating to the tensile properties of these alloys after different heat treatments, adequate information is lacking as to: (a) The effects of different normalizing treatments on static tensile and dynamic properties; (b) the effects of different methods of quenching and tempering on the dynamic properties; (c) the relation between the "lowering" of the transformations observed by Swinden[2] and the mechanical properties and structure. More especially are available data incomplete for commercial carbon-molybdenum steels, a study of which is essential to an understanding of the effects of small proportions of molybdenum in the heat treatment of more complex steels of the types previously indicated.

It was the purpose of this investigation to supplement the work of Swinden as regards the lowering of the transformations of a steel containing about 0.20 per cent carbon and 1 per cent molybdenum in order that a correlation with the mechanical properties of a single heat of steel might be attempted. It was likewise the intention of the author to compare different heat treatments for production of high resistance to impact and the best combinations of strength and ductility and to some extent to carry out parallel tests with a chromium-molybdenum steel.

1. M. H. Schmid: "Molybdenum Steel and Its Applications." Trans. Amer. Soc. Steel Treating, Vol I, No. 9 (June, 1921), p. 500. Ibid: Chem. & Met. Eng., 24 (May 25, 1921), p. 927.
2. T. Swinden: "A Study of the Constitution of Carbon-Molybdenum Steels." Journ. Iron & Steel Inst., 1913, No. 5, p. 100.

A paper presented at the Indianapolis Convention. The author, H. J. French, is physicist, Bureau of Standards, Washington, D. C. Published by permission of the director, Bureau of Standards.

A complete summary of available data relating to molybdenum steels will not be attempted but there follows a resume of the work of earlier investigators of general interest or more directly connected with the factors considered in this report. Thomas Blair[3], who was among the first to study the effects of molybdenum in iron alloys, reported a case where 1 per cent of this element rendered good iron red-short. Mathews[4] found only the first of three low carbon steels containing respectively 0.95, 1.87, and 2.99 per cent molybdenum could be cogged without difficulty and this was inclined to be seamy while the last two broke and cracked under a few blows of the hammer. Guillet[5] studied the properties of mild steels containing up to 9.3 per cent molybdenum and of 0.8 per cent carbon steels containing up to 14.6 per cent of this element and reported great difficulty in working some of them. It was impossible to work steels of the first series with more than 4.5 per cent molybdenum and those of the second with more than 2 per cent.

Mathews did not ascribe his results to the presence of molybdenum but rather to the quality of the alloy used in manufacturing the steels and this was substantiated by Brearley and Ibbotson[6] who stated that "experimenters are by no means unanimous with respect to the influence

3. Thomas Blair: "Tungsten and Chromium Alloys," 1894.
4. J. A. Mathews: "A Comparative Study of Some Low Carbon Steel Alloys," Journ. Iron & Steel Inst., 1902, No. 1, p. 182.
5. Leon Guillet: "Molybdenum Stee's." Rev. Met., 1904, p. 390.
6. H. Brearley and F. Ibbotson: "The Analysis of Steel Works Materials," 1920.

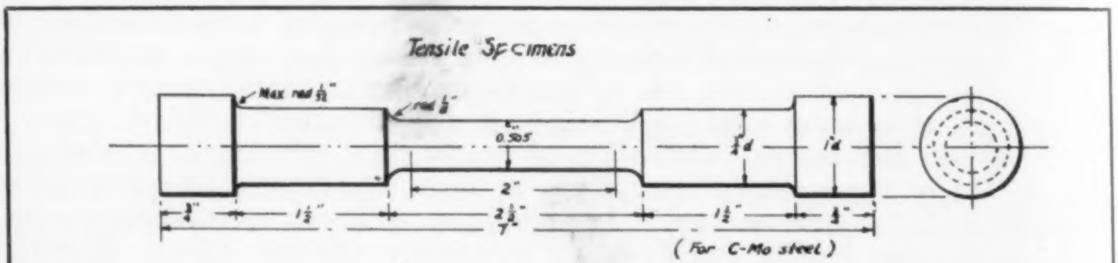


Fig. 1—Form and dimensions of test specimens used

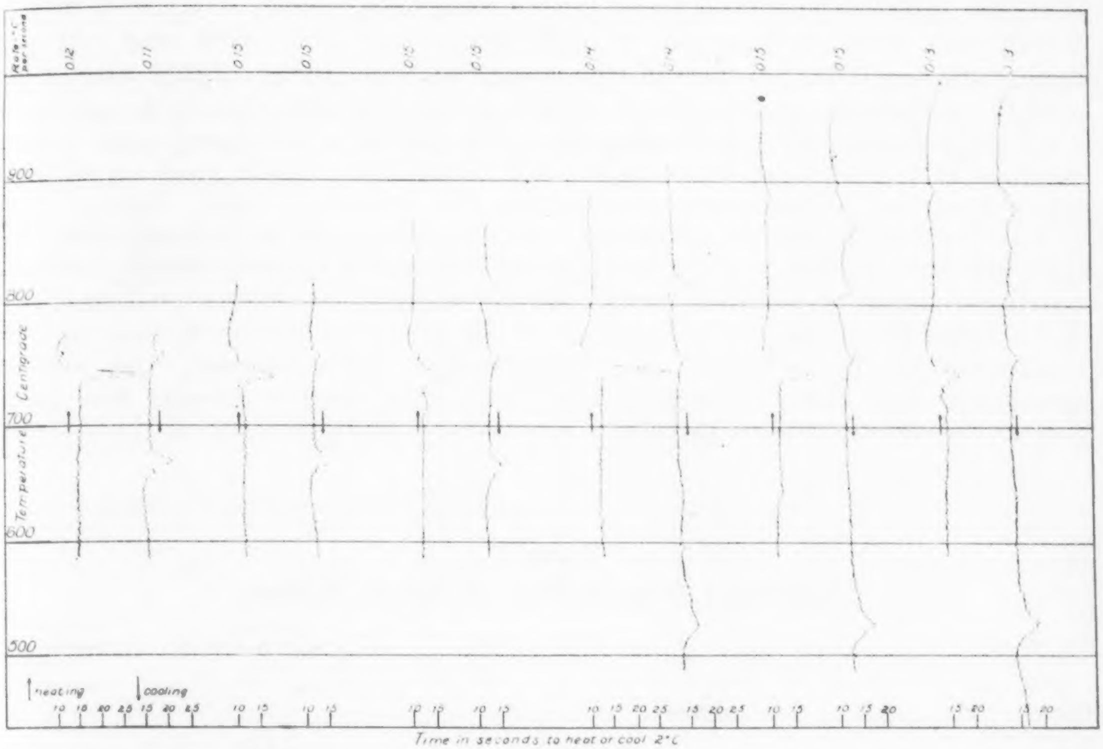


Fig. 2—Inverse-rate heating and cooling curves showing effects of maximum temperature of heating on the thermal transformations of a carbon-molybdenum steel

exerted by molybdenum on the mechanical properties of steel and according to our experience of the composition of the commercial alloys of this metal it would be surprising if they were". As more recently pointed out by Swinden[7], the proportion of sulphur and oxides in many of the powders used was sufficiently high to spoil the steel no matter how careful the melting.

Resulting from his investigation Guillet[8] classified molybdenum steels as follows:

Microstructure	Steel up to 0.20 per cent carbon	Steel up to 0.80 per cent carbon
Pearlite	0 to 2 per cent molybdenum	0 to 1 per cent molybdenum
Special constituent	Over 2 per cent molybdenum	Over 1 per cent molybdenum

The special constituent was considered by both Guillet and Portevin[9] to be double carbide. The low carbon steels with 0.50 to 1.0 per cent molybdenum showed an accentuated pearlitic structure which broke up when the proportion of this element was raised to 2 per cent while the 0.80 per cent carbon steels showed an extremely finely divided pearlite and the presence of the special constituent in increasing proportion as the molybdenum was increased above 1 per cent. Guillet also pointed out that the pearlitic steels showed excellent tensile properties with generally high yield point and good strength in torsion.

Swinden[10] carried out an elaborate series of tests on annealed, nor-

7. T. Swinden: "Carbon-Molybdenum Steels." Journ. Iron and Steel Inst., 1911, No. 3, p. 66.
8. See footnote 5.
9. A. M. Portevin: "Contribution to the Study of the Special Ternary Steels." Journ. Iron & Steel Inst., 1909, I, p. 275.
10. See footnote 7.

malized, hardened and tempered steels containing respectively 1, 2, 4, and 8 per cent molybdenum and in each series 0.20, 0.45, 0.85 and 1.15 per cent carbon. The pearlite of the annealed steels was highly emulsified and the saturation point, above which excess carbide appeared, was lowered with increase in molybdenum. No special constituent was distinguished in microscopic examination but results of carbide analysis showed more iron than necessary to account for the carbon as Fe_3C.

In later experiments Swinden[11] found that if the maximum temperature attained in heating did not exceed a certain definite value, dependent upon the proportion of molybdenum present, normal transformations were obtained in cooling regardless of the rate of heating or time at this temperature. If, however, this temperature was exceeded, the normal Ar_1 range was lowered or split and finally assumed a definite low position as the maximum temperature increased. The recovery of the normal

11. See footnote 2.

Table I
Chemical Composition of Steels Tested

Elements	Carbon-molybdenum steel, per cent	Chromium-molybdenum steel, per cent
Carbon	0.20	0.27
Manganese	0.41	1.01
Phosphorus	0.018	0.018
Sulphur	0.042	0.036
Silicon	0.22	0.20
Chromium	....	0.88
Molybdenum	0.94	0.52

Table II
Equipment Used in Determining Mechanical Properties

Test	Equipment Used
Tensile test	50,000-pound testing machine. Dial micrometers used in determining proportional limits
Impact test	120-foot-pound American made Izod type testing machine
Brinell hardness	American made Brinell hardness testing machine. 3000 kilogram load on 10 millimeter ball
Shore hardness	Recording scleroscope

Table III
Effect of Different Temperatures in Normalizing on the Mechanical Properties of a Carbon-Molybdenum Steel

Number	Heated for 30 minutes at temperature designated and air cooled, Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
A1	785	40,000	76,800	35	65.1	159	23	73—69—72
A2		37,000	76,600	36	65.8	159	25	
Average		38,500	76,700	35.5	65.4	159	24	71
A4	830	21,000	76,650	36	66.5	163	25	67—62—65
A5		22,500	76,750	35.5	68.1	159	23	
Average		21,750	76,700	35.8	67.3	161	24	65
B8	875	21,000	76,100	36	66	163	24	53—60—57
B9		25,000	76,800	35.5	66.3	163	25	
Average		23,000	76,450	35.8	66.2	163	24	57
B11	910	27,500	76,400	34.5	64.9	163	25	61—61—61
B12		31,800	76,250	32	63.1	163	24	
Average		29,650	76,325	33.2	64	163	24	61
C15	980	32,500	77,600	32	62.5	166	27	60—59—52
C16		31,500	77,000	32.5	62.8	166	26	
Average		32,000	77,300	32.2	62.6	166	26	57

Table IV

Effect of Different Quenching Temperatures on the Mechanical Properties of a Carbon-Molybdenum Steel Subsequently Quenched and Tempered at About 540 Degrees Cent. (1000 Degrees Fahr.)

Number	Held for 30 minutes at temperature designated and oil quenched. Subsequently tempered 30 minutes at 540 degrees Cent. Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
D26	785	58,000	88,650	24.5	51	179	29	
C29		57,000	88,750	24	53.5	179	30	
Average		57,500	88,700	24.2	52.3	179	30	
D25	830	70,000	104,500	20.5	51.7	207	33	48—49—47
D27		69,000	103,650	17	51	207	34	
Average		69,500	104,075	18.8	51.4	207	34	48
E37	875	74,000	104,400	21	62.5	228	37	65—65—74
E40		76,000	106,350	21	64.5	235	39	
Average		75,000	105,375	21	63	232	38	68
C28	910	78,000	110,500	23	65.5	241	38	70—68—68
C30		76,000	108,000	22.5	65.5	248	39	
Average		77,000	109,250	22.8	65.5	245	38	69
F38	980	76,000	105,250	23.5	65	235	36	67—68—67
F47		76,000	106,750	23	64.5	235	36	
Average		76,000	106,000	23.2	64.8	235	36	67

transformation was only obtained by repeated reheating to below the lowering temperature.

Based on these facts and determination of electrical resistivity, hardness, tensile properties and microstructure he concluded that "the molybdenum does not exist as double carbide and is not in solid solution in the iron but probably dispersed in the ferrite in a manner suggesting the existence of a solid colloidal solution of an iron-molybdenum compound in iron. The lowering temperature marks a change in state of the molybdenum, or iron-molybdenum compound in iron and the separation of Fe_3C is delayed until the low point temperature is reached". Swinden also found that molybdenum did not increase the Brinell hardness of annealed steels nor those quenched from 800 degrees Cent. but in samples quenched from 1200 degrees Cent., an increase in hardness was obtained which was greater the higher the molybdenum.

Arnold and Read[12] prepared a series of steels containing about 0.8 per cent carbon and from 2.4 to 20.7 per cent molybdenum and subjected annealed samples to tensile and alternating stress tests using the Arnold machine. Excessively poor results were obtained in the latter, confirming Swinden's earlier conclusion that annealing deteriorated the mechanical properties of molybdenum steels. Based on the electrolytic isolation of carbides and analysis of the carbide residue, as carried out in their study of tungsten steels[13], the authors concluded that molybdenum formed a double carbide with iron which completely replaced the cementite in the presence of about 18.25 per cent molybdenum. High proportions of this element appeared to facilitate the segregation of ferro-molybdenum-cementite in the annealed steels.

12. J. O. Arnold and A. A. Read: "The Chemical and Mechanical Relations of Iron, Molybdenum and Carbon." Proc. Inst. Mech Engs., 1915, No. 2, p. 629.

13. J. O. Arnold and A. A. Read: "The Chemical and Mechanical Relations of Iron, Tungsten, and Carbon." Proc. Inst. Mech. Engs., 1914, p. 223.

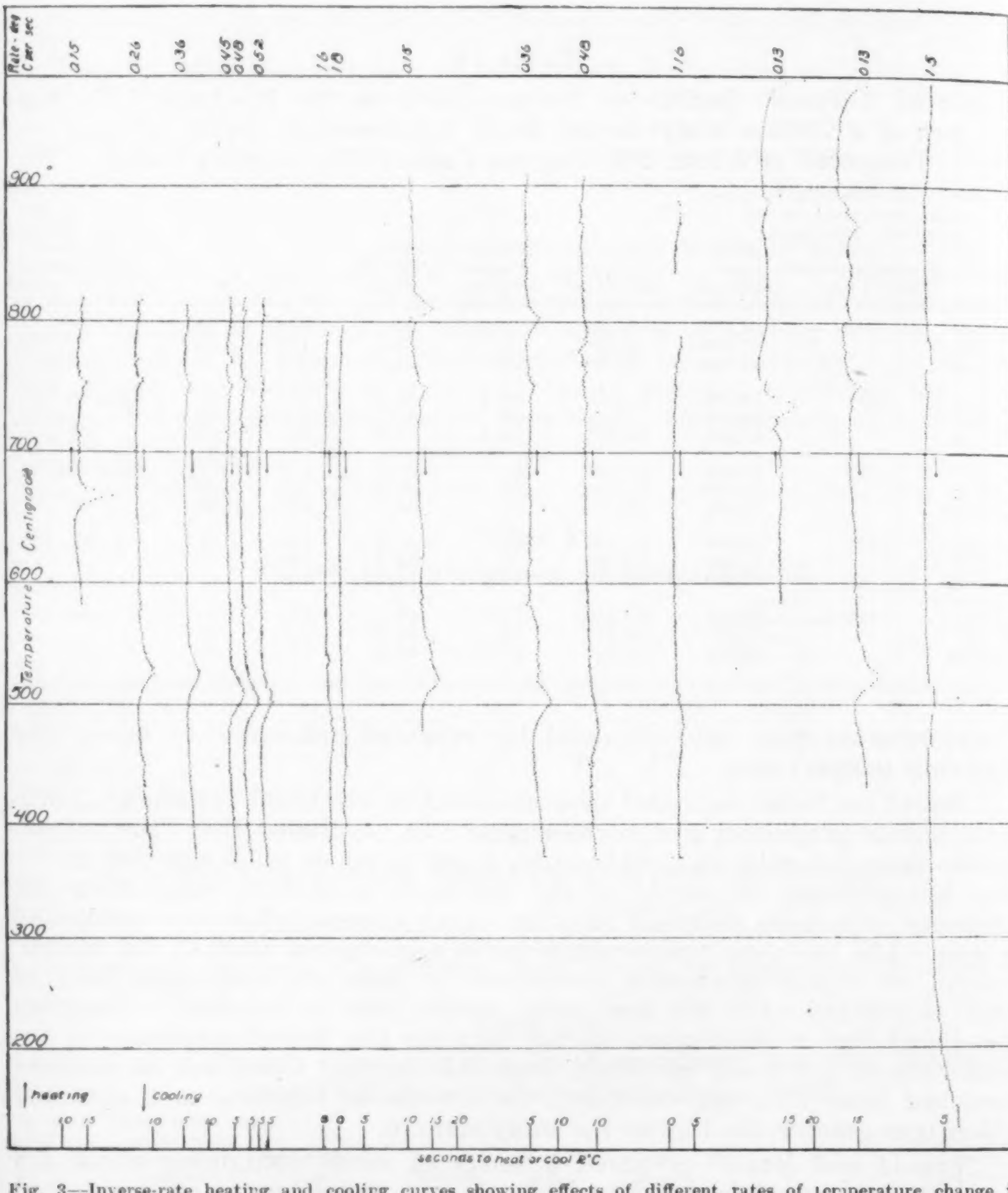


Fig. 3—Inverse-rate heating and cooling curves showing effects of different rates of temperature change in cooling from various temperatures on the transformations of a carbon-molybdenum steel

In an appendix to the work of Arnold and Read, Hadfield[14] called attention to the fact that the influence of molybdenum, per se, upon iron was small and without the presence of other elements was not likely to be of importance. In making his series of alloys containing varying proportions of carbon and molybdenum, the latter was introduced in two ways. More uniform results were obtained with the use of metallic molybdenum than with a ferroalloy, and as cast and forged the steels showed generally low elastic limits.

Recently Sargent[15] published the results of a large number of tensile

14. Sir R. A. Hadfield: "Alloys of Iron and Molybdenum." Proc. Inst. Mech. Engs., 1915, No. 2, p. 701.

15. G. W. Sargent: "Molybdenum as an Alloying Element in Structural Steels." Proc. Amer. Soc. Test. Mats., 1920.

tests obtained on different structural alloy steels. When subjected to various thermal treatments the steels containing small proportions of molybdenum, 0.25 to 1.0 per cent, showed tensile properties superior to those without. Attention was called to the very small effect on tensile properties of wide variations in hardening temperatures and to the more gradual decrease in strength of the hardened molybdenum steels with rise in tempering temperature. Generally high values were obtained for the reduction of area. The advantages obtained by adding small propor-

Table V

Mechanical Properties of a Carbon-Molybdenum Steel Quenched in Different Media from Various Temperatures With and Without Preliminary Normalizing

No.	Heat Treatment	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
G55	830°C–30 min–Oil	42,500	107,150	8	28.5	248	44	15—16—16
G56		43,000	117,250	8	31	235	43	
Average		42,750	117,200	8	29.8	242	44	16
K82	830°C–30 min–Water	51,000	176,900	8.5	24.6	321	55	20—16—12
K83		49,000	160,000	5	12	311	53	
Average		50,000	168,450	6.8	18.3	316	54	16
H57	910°C–30 min–Oil	46,500	111,250	20	52.5	235	39	57—53—59
H58		46,500	111,250	16	50	235	40	
Average		46,500	111,250	18	51.3	235	40	56
J76	910°C–30 min–Water	38,500	134,200	9	31	302	47	39—37—39
J77		37,500	132,000	10.5	31.5	286	45	
Average		38,000	133,100	9.8	31.2	294	46	38
G52	910°C–30 min–Air, then	35,000	104,230	17.5	39.2	228	33	19—20—20
G53	830°C–30 min–Oil	37,000	106,500	17.5	35.5	223	36	
Average		36,000	105,360	17.5	37.9	223	34	20
K79	910°C–30 min–Air, then	46,500	154,350	8.5	34.5	302	52	11—22—29
K80	830°C–30 min–Water	41,000	135,700	9.5	42.2	277	48	
Average		43,750	145,025	9	38.4	290	50	21

Table VI

Hardness of a Carbon-Molybdenum Steel Cooled at Different Rates from Various Temperatures to Produce the Normal or Lowered Ar_1 Transformation*

Sample Number	Maximum Temperature of Heating, Degrees Cent.	Rate of Cooling, Degrees Cent. per Second	Hardness Shore	Hardness Rockwell	Ar_1 (lowered or normal)	Transformations observed above Ar_3, Degrees Cent.
A131–1	788	0.15	25	44	Normal	...
A131–2	870	0.15	24	45	Normal	...
A131–3	912	0.15	22	47	Low	865
A131	978	0.13	24	44	Low	875
A131–A	835	0.26	24	48	Low	...
A131–C	841	0.36	24	47	Low	...
A131–B	837	0.45	24	48	Low	...
A131–D	839	0.48	26	49	Low	...
A131–E	835	0.51	25	49	Low	...
A131–K	804	1.53	26	49	Low	...
A131–L	819	1.80	25	47	Low	...
A131–3*	912	0.15	22	47	Low	865
A131–F	928	0.36	24	47	Low	...
A131–G	923	0.48	25	50	Low	...
A131–H	910	0.48	24	50	Low	...
A131–J	925	1.16	25	47	Low	...

*Samples are those for which heating and cooling curves are given in Figs. 7, 8 and 9. They were heated and cooled in vacuum.

tions of molybdenum to structural carbon and alloy steels, emphasized by Sargent, have in general been substantiated in recent publications by McKnight[16], Schmid[17], and Hunter[18].

The steel tested was obtained from the Carbon Steel Co., Pittsburgh, through the courtesy of the Climax Molybdenum Co., New York. The results obtained from analysis of the bars which were received in the form of 1-inch or ½-inch chromium molybdenum hot rolled rounds, are given in Table I.

All bars were first cut into suitable lengths for triple notch Izod impact and tensile test specimens. These blanks were roughly machined to slightly greater than the required size for test specimens, as shown in Fig. 1, heat treated, finish machined and tested. All treatments were carried out in electric resistance furnaces except when tempering at 230 degrees Cent. in which case an oil bath was used. Temperatures were obtained by a 22-gage base metal thermocouple connected to a potentiometer. Tensile and impact specimens were heat treated simultaneously and for hardening were brought up to temperature with the furnace, while in tempering the sample was introduced in the heating unit at about 50 degrees Cent. (90 degrees Fahr.) below the desired temperatures. Mechanical tests of the heat treated metal were made with the instruments and under conditions given in Table II. Thermal transformations were determined by the inverse rate method[19] which has already been described in detail by Scott and Freeman[20].

In Fig. 2 are given heating and cooling curves obtained at a rate of temperature change approximating 0.15 degrees Cent. (0.27 degrees Fahr.) per second for samples heated to different temperatures between about 790 and 980 degrees Cent. (1450 and 1800 degrees Fahr.) and it will be noted that in all curves the A2 transformation is clearly shown at about 760 degrees Cent. (1400 degrees Fahr.). When cooling from about 870 degrees Cent. (1600 degrees Fahr.), thermal transformations are found like those observed in plain carbon steels of similar carbon content but when the initial temperature T_{max} is raised about 40 degrees Cent. (70 degrees Fahr.) to 910 degrees Cent. (1670 degrees Fahr.) Ar is lowered about 135 degrees Cent. (245 degrees Fahr.) from 660 to 525 degrees Cent. (1220 to 975 degrees Fahr.). With further rise in the maximum temperature of heating the position of the "low point" remains practically unchanged.

These results as regards the lowering or splitting of Ar_1 agree closely with those obtained by Swinden[21] for steel of similar composition. However, an additional transformation, in the neighborhood of 860 degrees Cent. (1580 degrees Fahr.) is observed in curves obtained by the present author when the steel is cooled from 960 degrees Cent. (1760 degrees Fahr.) or a temperature above.

Lowering of Ar_1 is not produced, when cooling at about 0.15 degrees Cent. (0.27 degrees Fahr.) per second, until an initial temperature

16. C. McKnight, Jr.: "A Discussion of Molybdenum Steels." Trans. Amer. Soc. Steel Treating, Vol. I, No. 6 (March, 1921), p. 288.
17. See footnote 1.
18. A. H. Hunter: "Physical Properties of Molybdenum Steel." Chem. & Met. Eng., 25 (July 6, 1921), p. 21.
19. The author is indebted to the Misses I. Wymore, assistant chemist and M. Preble, laboratory aid, for the heating and cooling curves shown in this report.
20. Bureau of Standards Scientific Paper 348.
21. See footnote 2.

Table VII

Mechanical Properties of a Carbon-Molybdenum Steel Tempered at Various Temperatures After Hardening in Different Ways

Number	Held for 30 minutes at temperatures designated and air cooled, Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
Steel Heated 30 Minutes at 830 Degrees Cent. and Oil Quenched								
G55	...	42,500	117,150	8	28.5	248	44	15—16—16
G56		43,000	117,250	8	31	235	43	
Average		42,750	117,200	8	29.8	242	44	16
E39	230	32,000	117,750	12	34.5	228	38	26—28—28
C23		27,000	112,250	13	37	228	38	
Average		29,500	115,000	12.5	35.8	228	38	27
H59	400	67,500	104,850	19.5	54.5	215	35	44—44—42
G51		68,000	104,850	21.5	54.5	215	35	
Average		67,750	104,850	20.5	54.5	215	35	43
D25	538	70,000	104,500	20.5	51.7	207	33	48—49—47
D27		69,000	103,650	17	51	207	34	
Average		69,500	104,075	18.8	51.4	207	34	48
Steel Heated 30 Minutes at 830 Degrees Cent. and Water Quenched								
K82	...	51,000	176,900	8.5	24.6	321	55	20—16—12
K83		49,000	160,000	5	12	311	53	
Average		50,000	168,450	6.8	18.3	316	54	16
F45	400	80,000	141,100	13.5	46.5	266	45	23—23—24
F44		83,000	146,500	12.5	45.7	269	49	
Average		81,500	143,800	13	46.1	268	47	23
C18	538	99,000	129,850	17	51.5	248	42	36—37—38
C24		100,000	131,500	17.5	49	255	45	
Average		99,500	130,675	17.2	50.2	252	44	37
F46	675	91,000	102,750	22	63.5	207	37	76—82—77
G54		89,000	101,300	22	64	207	35	
Average		90,000	102,025	22	63.8	207	36	78
Steel Heated 30 Minutes at 910 Degrees Cent. and Oil Quenched								
H57	...	46,500	111,250	20	52.5	235	39	57—53—59
H58		46,500	111,250	16	50	235	40	
Average		46,500	111,250	18	51.3	235	40	56
J74	230	40,000	102,800	23	64	223	37	50—68—73
L85		41,000	105,000	21	61	235	38	
Average		40,500	103,900	22	62.5	229	38	64
L89	400	62,000	104,500	18.5	65	228	38	72—72—74
M94		63,000	105,500	19	63	203	35	
Average		62,500	105,000	18.8	64	216	36	73
C28	538	78,000	110,500	23	65.5	241	38	70—68—68
C30		76,000	108,000	22.5	65.5	248	39	
Average		77,000	109,250	22.8	65.5	245	38	69
Steel Heated 30 Minutes at 910 Degrees Cent. and Water Quenched								
J76	...	38,500	134,200	9	31	302	47	39—37—39
J77		37,500	132,000	10.5	31.5	286	45	
Average		38,000	133,100	9.8	31.2	294	46	38
L86	400	121,000	166,500	11	49	277	53	35—43—54
L88		126,500	171,900	11.5	50	293	56	
Average		123,750	169,200	11.2	49.5	285	54	44
H60	538	93,000	120,800	14.5	59.5	269	48	46—45—44
I70		119,000	150,600	16	53.2	277	47	
Average		106,000	135,700	15.2	56.4	273	48	45
I71	675	102,000	111,350	20	63	228	38	76—67—72
I73		104,000	113,050	20.5	61.5	241	41	
Average		103,000	112,200	20.2	62.2	235	40	72

of about 910 degrees Cent. (1670 degrees Fahr.) is reached but it is obtained from lower temperatures if more rapid cooling is used. The effects of rate of temperature change on the transformations of the steel under consideration when cooling from about 830 degrees Cent. (1525 degrees Fahr.), 910 degrees Cent. (1670 degrees Fahr.) or 980 degrees Cent. (1795 degrees Fahr.) are shown in Fig. 3, and the position of the "low point" is not lowered materially with increasing speed of cooling

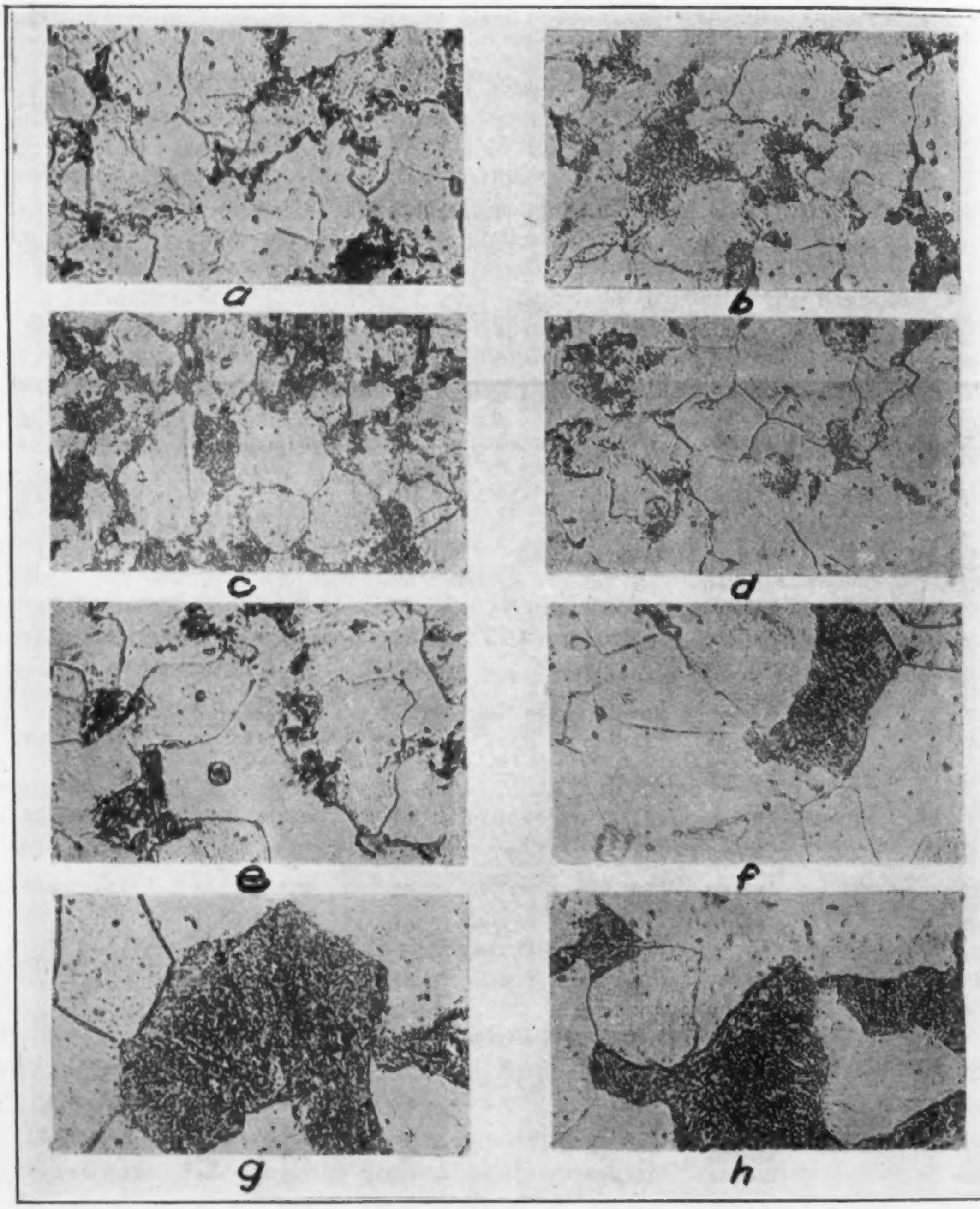


Fig. 4—Structures of a carbon-molybdenum steel cooled at different rates from various temperatures. X 500. Etched with 2 per cent nitric acid in alcohol. *a*. Cooled from 788 degrees Cent. at 0.15 degrees Cent. per second. *b*. Cooled from 830 degrees Cent. at 0.15 degrees Cent. per second. *c*. Cooled from 830 degrees Cent. at 1.80 degrees Cent. per second. *d*. Cooled from 870 degrees Cent. at 0.15 degrees Cent. per second. *e*. Cooled from 912 degrees Cent. at 0.15 degrees Cent. per second. *f*. Cooled from 912 degrees Cent. at 1.16 degrees Cént. per second. *g*. Cooled from 980 degrees Cent. at 0.15 degrees Cent. per second. *h*. Cooled from 980 degrees Cent. at 1.50 degrees Cent. per second

but is gradually suppressed. The position of Ar_2 remains unchanged but Ar_3 is lowered slightly and its magnitude decreases as the rate of cooling increases. The broad high temperature transformation which occurs above and nearly merges with Ar_3 in the sample cooled from about 980 degrees Cent. (1795 degrees Fahr.) at 0.15 degrees Cent. (0.27 degrees Fahr.) per second disappears when the steel is cooled at a much faster rate.

It appears that for each initial temperature there is a critical rate of cooling which will produce lowering of Ar_1 and that the higher T_{max} the slower is the rate of temperature change required to do this. Also the position of the lowered transformation is fixed (confirming Swinden) within a comparatively narrow temperature range about 525 degrees Cent. (975 degrees Fahr.) regardless of the maximum temperature of heating or rate of cooling within the limits covered by the experiments, but it is relatively easy to suppress the lowered thermal effect entirely. While the structures obtained after cooling in the different ways shown in Figs. 2 and 3 are interesting they do not throw a great deal of light upon the character of the observed changes.

In all cases the eutectoid appears highly emulsified, as shown in Fig. 4, and not like the characteristic structure of pearlite found in slowly cooled carbon steels, a condition which has already been noted by Swinden[22], Guillet[23] and others. In those samples cooled from the highest temperatures it appears in large well defined grains as is particularly well shown in Fig. 4*g*, while when very slowly cooled from the lowest temperature, 830 degrees Cent. (1525 degrees Fahr.), it is distributed in smaller masses, the boundaries of which are not so well defined. The highly emulsified eutectoid, probably equivalent to sorbite in plain carbon steels, is rather to be expected in view of the lowered Ar_1 transformation but this type of structure is also observed in samples in which the normal transformations are obtained.

Hardness and tensile properties, excepting limit of proportionality, are not changed greatly by varying the temperature from which the steel is cooled in air as shown in Fig. 5 and Table III. However, there is a general decrease in the Izod impact value as the maximum temperature is raised from 785 to 980 degrees Cent. (1445 to 1795 degrees Fahr.). The lowest value of proportional limit is observed when cooling from 830 degrees Cent. (1525 degrees Fahr.) which is at or slightly above Ac_3 but increases with elevation of the normalizing temperature. Structures of the steel subjected to the various treatments shown in Table III are similar to those given in Fig. 4.

The effect of varying oil hardening temperatures on the mechanical properties of steel subsequently tempered at about 540 degrees Cent. (1000 degrees Fahr.) is marked as shown in Fig. 6 and Table IV. The best combinations of tensile and impact properties are obtained in those samples quenched from about 910 degrees Cent. (1670 degrees Fahr.) which is about 40 degrees Cent. (70 degrees Fahr.) above the lowest temperature at which all ferrite is held in solution, Fig. 7, and simultaneous increase in tensile strength, limit of proportionality, reduction of area and impact energy absorbed (Izod) is observed when the quenching temperature is raised from just at or above Ac_3, 830 degrees Cent. (1525

22. See footnote 2.
23. See footnote 5.

degrees Fahr.), to this temperature. Obviously the lower of these two temperatures is too close to the end of Ac_3 to permit satisfactory hardening as indicated by the free ferrite obtained even after quenching in water as shown in Fig. 8.

However, this does not explain adequately the observed changes in mechanical properties, or the brittleness of steel quenched in oil or water from 830 degrees Cent. (1525 degrees Fahr.) and not subsequently tempered as shown in Table V, nor can this be used to explain the higher ductility and resistance to impact, together with lower strength, observed

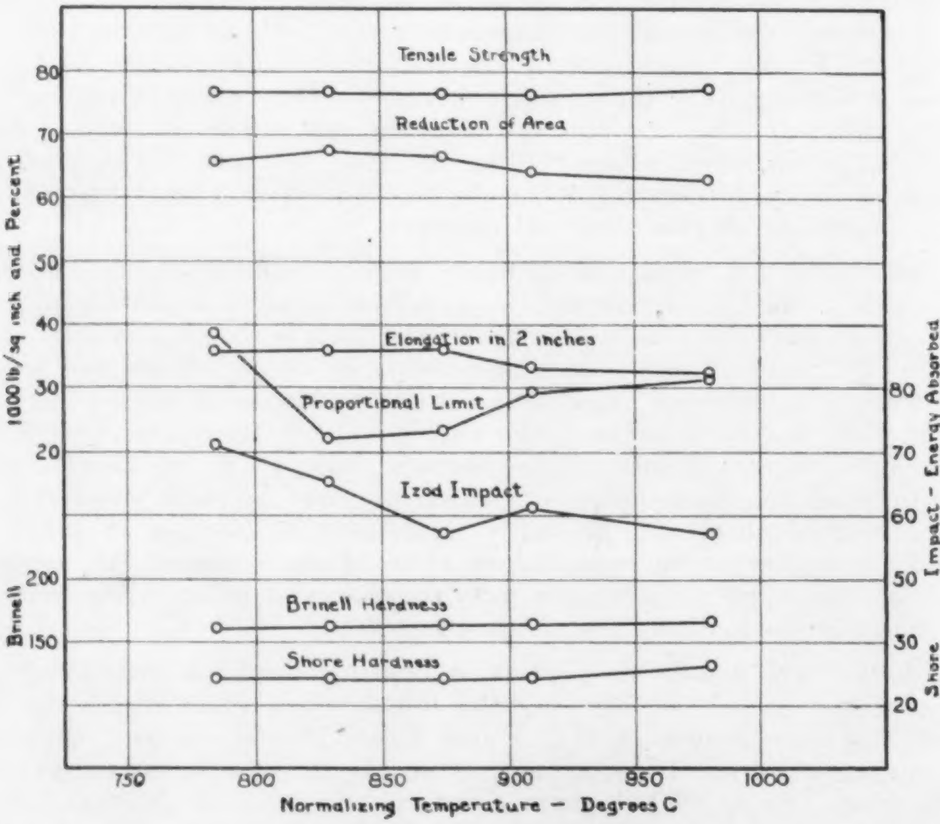


Fig. 5—Effect of different temperatures in normalizing on the mechanical properties of a carbon-molybdenum steel

in quenching in a given medium from a higher temperature, 910 degrees Cent. (1670 degrees Fahr.), for it has been shown[24] that the higher the temperature of heating within limits, the more rapidly does steel of constant mass pass through the transformations which results in a harder and more brittle product. That an increase in quenching temperature results in higher strength and lower ductility for 0.20 per cent carbon steel without molybdenum is shown by the results obtained by Roberts-Austin and Gowland[25]. The observed changes in mechanical properties of the molybdenum steel are therefore opposite to those which might, at the outset, be expected and which are obtained in carbon steel.

These changes cannot be ascribed to the lowering of Ar_1 and hence

24. C. Benedicks: "Experimental Researches on the Cooling Power of Liquids, on Quenching Velocities and on the Constituents Troostite and Austenite." Journ. I. & S. Inst., 1908, Vol. 2. p. 153.
25. Sir W. Roberts-Austen and W. Gowland: Sixth Report to the Alloys Research Committee: "On the Heat Treatment of Steel." Proc. Inst. Mech. Eng., 1904, Vol. I, p. 7.

a carbon change for it has been found that lowering of this transformation is produced when cooling from 830 degrees Cent. (1525 degrees Fahr.) at about 0.26 degrees Cent. (0.45 degrees Fahr.) per second which is much slower than the rate of cooling in oil or water. With higher initial temperatures the lowered Ar_1 transformation is produced at even slower rates. Also a lowering of Ar_1 would tend to harden the steel. By elimination they must therefore be ascribed, at least in part, to a molyb-

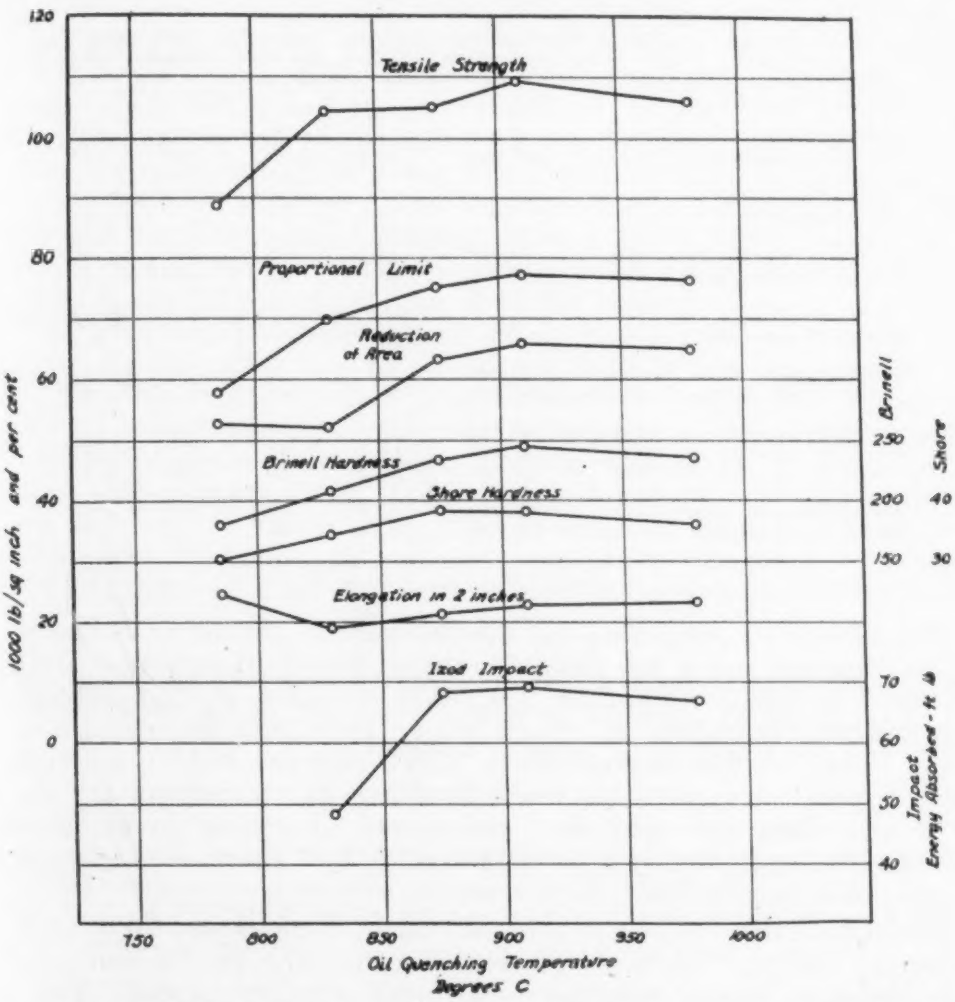


Fig. 6—Effect of different quenching temperatures on the mechanical properties of a carbon-molybdenum steel subsequently oil quenched and tempered at about 540 degrees Cent. (1000 degrees Fahr.)

denum change which under certain conditions takes place between about 830 and 870 degrees Cent (1525 and 1600 degrees Fahr.).

The nature of this change is obscure and microscopic examination does not reveal any features which might assist in an explanation. In this connection it is of interest to note that there are no recognizable variations in hardness as determined by the Shore and Rockwell methods between samples showing normal transformations and those in which the "low point" is produced, Table VI, nor are there differences between the hardness of samples in which the high temperature thermal effect is observed and those without. Probably the change is one in solid solution, in the form and distribution of an iron-molybdenum compound in iron, the condition in which molybdenum is conceived to exist by Swinden.

Table VIII

Comparison of the Mechanical Properties of a Carbon-Molybdenum Steel Heat Treated in Different Ways to Produce Definite Strengths

(Approximation)

Desired Tensile Strength, pounds per square inch	Method of Hardening	Tempering Required (30 minutes) at degrees Cent.	Proportional Limit, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Impact Energy Absorbed foot-pounds (120-foot-pound Izod machine)
165,000	830°C–30 min–Oil	Cannot obtain desired strength						
	910°C–30 min–Oil							
	830°C–30 min–Water	(60)	85,000	8.5	22	310	53	17
	910°C–30 min–Water	420	121,000	11.5	50	283	53	44
150,000	830°C–30 min–Oil	Cannot obtain desired strength						
	910°C–30 min–Oil							
	830°C–30 min–Water	300	74,000	11.5	39	230	49	22
	910°C–30 min–Water	485	113,000	13.5	54	280	50	44
125,000	830°C–30 min–Oil	Cannot obtain desired strength						
	910°C–30 min–Oil							
	830°C–30 min–Water	565	98,000	18	52	245	43	44
	910°C–30 min–Water	610	105,000	17.5	60	255	44	53
110,000	830°C–30 min–Oil	315	49,000	16.5	45	225	36	35
	910°C–30 min–Oil	(45)	45,000	19	54	235	39	57
		540	77,000	22.5	66	245	38	69
	830°C–30 min–Water	630	93,000	20.5	59	225	39	64
	910°C–30 min–Water	685	103,000	20.5	62	235	39	73

The effects of tempering on the mechanical properties of steel hardened in different ways are shown in Figs. 9 and 10 based on data given in Table VII and will not be described in detail as the difference between samples quenched in oil or water from 830 degrees Cent. (1525 degrees Fahr.) or 910 degrees Cent. (1670 degrees Fahr.) are fully indicated. Typical structures obtained by different treatments are shown in Fig. 11 and show the similarity, mentioned by earlier investigators, between samples quenched in a definite manner and those simliarly quenched and tempered at relatively high temperatures.

By interpolation of the graphs shown in Figs. 9 and 10 it is possible to compare different methods of treatment for the production of definite tensile strength, impact resistance, hardness or other factors. The results of such approximations for the production of definite tensile strengths and impact values, are given in Tables VIII and IX and these data show certain features of interest.

1. For the production of tensile strengths between 150,000 and 165,000 pounds per square inch higher elastic ratio and impact values and better ductility are obtained by quenching in water from 910 degrees Cent. (1670 degrees Fahr.) than from 830 degrees Cent. (1525 degrees Fahr.). Tensile strengths within the limits given, of course, cannot be developed by oil hardening. Likewise a higher tempering temperature is required to produce a given strength when quenching from the higher temperature, 910 degrees Cent. (1670 degrees Fahr.).

2. To produce a tensile strength in the neighborhood of 110,000 to 125,000 pounds per square inch water quenching from either 910 degrees Cent. (1670 degrees Fahr.) or 830 degrees Cent. (1525 degrees

Fahr.) is to be preferred as a higher elastic ratio is produced than when quenching in oil from either of these temperatures. The highest impact values are produced by quenching in water from the higher temperature, while when quenching from the same temperature in oil slightly better results are obtained than when quenching from 830 degrees Cent. (1525 degrees Fahr.) in either oil or water. Variations in ductility are not so marked when using the various methods of hardening, except when quenching in oil from 830 degrees Cent. (1525 degrees Fahr.) as when producing strengths of 150,000 to 165,000 pounds per square inch. The tempering temperatures required to produce definite strengths within the stated range, 110,000 to 125,000 pounds per square inch, decrease in the following order for the different hardening methods used: 910 degrees Cent. (1670 degrees Fahr.) water; 830 degrees Cent. (1525 degrees Fahr.) water; 910 degrees Cent. (1670 degrees Fahr.) oil; 830 degrees Cent. (1525 degrees Fahr.) oil. These treatments are likewise in the order of decreasing limits of proportionality and the lowest value obtained is less than half the highest.

3. In general, specimens quenched in water and subsequently tempered to a degree necessary to produce a definite tensile strength show higher resistance to impact than do specimens of the same tensile strength produced by oil quenching and better results are obtained when quenching from 910 degrees Cent. (1670 degrees Fahr.) in a given medium than from 830 degrees Cent. (1525 degrees Fahr.). By suitable treatment an increase of more than 100 per cent in impact values can be obtained while the strength remains practically constant. Conversely,

Table IX

Comparison of the Mechanical Properties of a Carbon-Molybdenum Steel Heat Treated in Different Ways to Produce Definite Izod Impact Values

(Approximation)

Desired Izod Impact Value, (120-foot-pound Machine Energy Absorbed) Foot-pounds	Method of Hardening or Normalizing	Tempering Required, (30 minutes) at Degrees Cent.	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore
40	830°C–30 min–Oil	375	62,000	106,000	19	51	217	35
	910°C–30 min–Oil	All impact values higher than that chosen						
	830°C–30 min–Water	550	99,000	128,000	17.5	51	250	43
	910°C–30 min–Water	150	70,000	159,000	10	38	290	49
55	830°C–30 min–Oil	Tempering at over 538 degrees Cent. required; not included in tests made.						
	910°C–30 min–Oil	None	46,000	111,000	18	51	235	40
	830°C–30 min–Water	600	95,000	116,000	19	56	230	40
	910°C–30 min–Water	599	102,000	139,000	17	59	260	45
65	830°C–30 min–Oil	Tempering at over 538 degrees Cent. required if possible to obtain chosen impact value; not included in tests made						
	910°C–30 min–Oil	250	43,000	104,000	21.5	63	227	38
	830°C–30 min–Water	630	93,000	109,000	20.5	59	220	38
	910°C–30 min–Water	640	104,000	119,000	19	60	245	42
	830°C–30 min–Air	...	22,000	77,000	35.5	67	161	24
70	830°C–30 min–Oil	Tempering at over 538 degrees Cent. required if possible to obtain chosen impact values; not included in tests made.						
	910°C–30 min–Oil	500	73,000	108,000	21.5	65	235	37
	830°C–30 min–Water	650	92,000	105,000	21	61	215	37
	910°C–30 min–Water	665	103,000	114,000	19.5	62	237	40

for the production of definite impact values, higher tensile strength and better combinations of limit of proportionality and ductility may be obtained.

One of the most widely recommended of the molybdenum steels

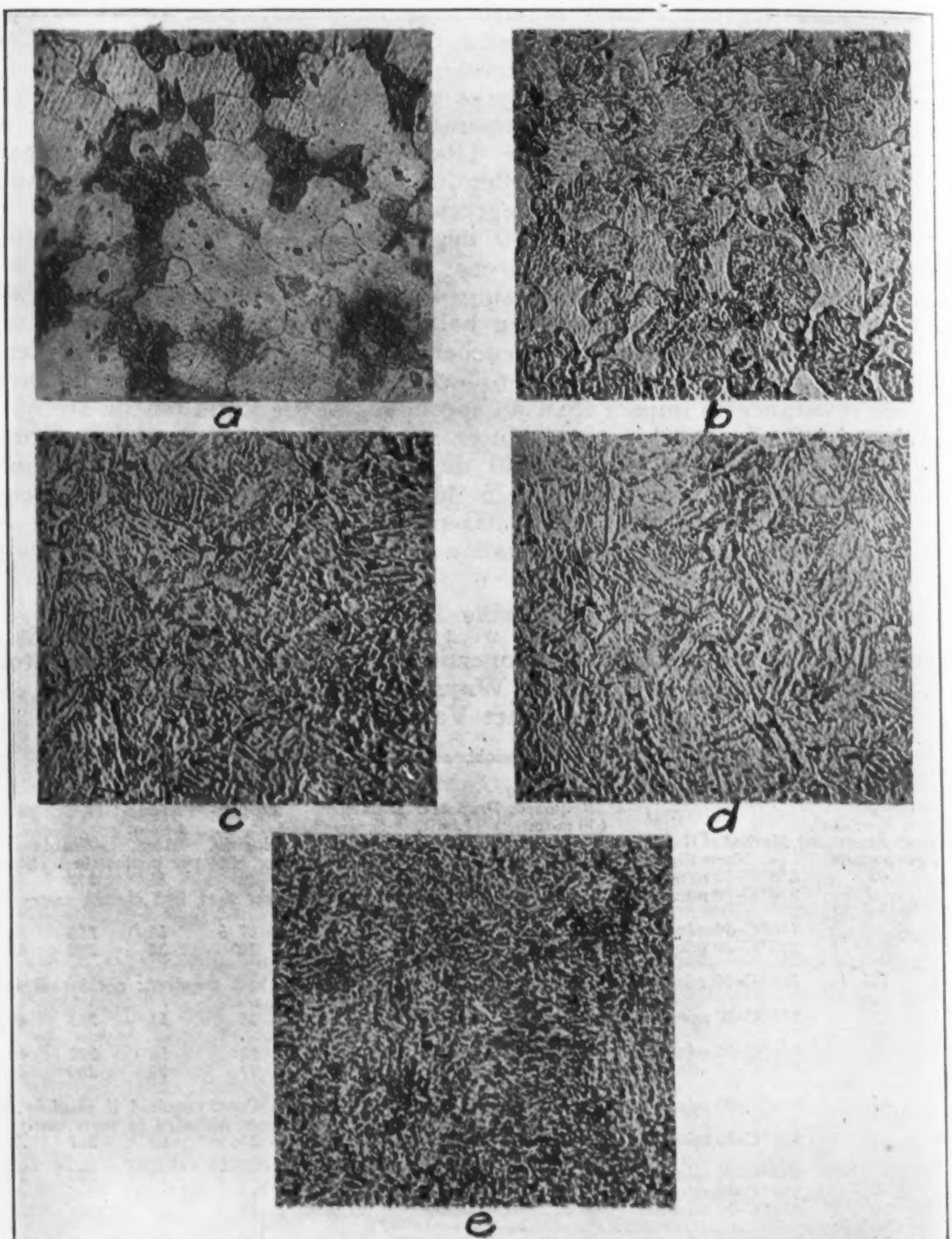


Fig. 7—Structures of a carbon-molybdenum steel oil quenched from different temperatures and subsequently tempered at about 540 degrees Cent. (1000 degrees Fahr.). X 500. Etched with 2 per cent c. Oil quenched from 875 degrees Cent. d. Oil quenched from 910 degrees Cent. e. Oil quenched from nitric acid in alcohol. a. Oil quenched from 785 degrees Cent. b. Oil quenched from 830 degrees Cent. 980 degrees Cent.

for structural purposes is that containing 0.8 to 1 per cent of chromium and about 0.5 per cent of molybdenum. For comparison with the carbon molybdenum steel previously considered, inverse rate heating and cooling curves were obtained on samples of the composition given in Table I. As shown in Fig. 12, one transformation is observed in heating while $Ar_{3\text{-}2}$ and the pearlite change Ar_1 are shown in cooling. With increase in the maximum temperature of heating and a rate of temperature change of 0.15 degrees Cent. (0.27 degrees Fahr.) per second, the latter is first split in cooling from about 960 degrees Cent. (1760 degrese Fahr.). In this case, however, the upper point of the split transformation remains pronounced and occurs at the same temperature as normal Ar_1 while the "low" point is barely visible. With rise in in-

Table X

Effect of Normalizing Temperatures on the Mechanical Properties of a Chromium-Molybdenum Steel

Number	Treatment Heated 30 minutes at temperatures designated and air cooled	Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness Brinell	Hardness Shore	Izod Impact (Round) foot-pound
9	730°C. 1350°F.	85,500	106,100	19	64.2	237	37	76—78—78
11		85,000	105,100	20	64.4	207	37	78—75—74
Average		85,250	105,600	19.5	64.3	222	37	76
13	790°C. 1450°F.	74,500	96,000	23	68.4	199	36	86—85—84
15		66,500	94,300	24	68.6	207	36	82—81—81
Average		70,500	95,150	23.5	68.5	203	36	83
17	815°C. 1500°F.	47,000	109,600	19	56.2 *	235	38	20—34
19		48,000	98,200	20	65.1	228	38	21—20
Average		47,500	103,900	19.5	60.6	232	38	24
21	845°C. 1550°F.	28,500	112,500	19.5	49.6	241	39	21—21—25
25		29,500	111,900	19.5	49.6	228	39	26—21—25
Average		29,000	112,200	19.5	49.6	235	39	23
23	870°C. 1600°F.	52,000	117,000	18.5	56	258	42	20—24—29
27		51,000	115,000	17.5	53.1	228	40	24—24—31
Average		51,500	116,050	18	54.6	243	41	25

itial temperature to about 1000 degrees Cent. (1830 degrees Fahr.) the magnitude of the low temperature thermal effect increases and that of the upper decreases but both remain in their respective positions on the temperature scale. Microphotographs of samples heated to either 960 or 1000 degrees Cent. (1760 or 1830 degrees Fahr.) and thereafter slowly cooled in a furnace to different temperatures before quenching in water to retain in large part the existing structures are shown in Fig. 13.

As quenched in water from either 960 or 1000 degrees Cent. (1760 or 1830 degrees Fahr.), the steel is martensitic and has a Brinell hardness of 477 to 495. When first slowly cooled from 960 degrees Cent. (1760 degrees Fahr.) to just below $Ar_{3\text{-}2}$ before quenching, large grains of precipitated ferrite are found and the eutectoid exists as troostosorbite, as shown in Fig. 13*c*. The Brinell hardness of this sample (340) is very nearly the same as that which has been heated to 1000 degrees Cent. (1830 degrees Fahr.) and similarly cooled but the eutectoid in this latter case resembles martensite. When the steel is heated to 1000 degrees Cent. (1830 degrees Fahr.) and slowly cooled to a lower temperature about midway between the upper and lower points of the split Ar_1 transformation, 590 degrees Cent. (1095 degrees Fahr.),

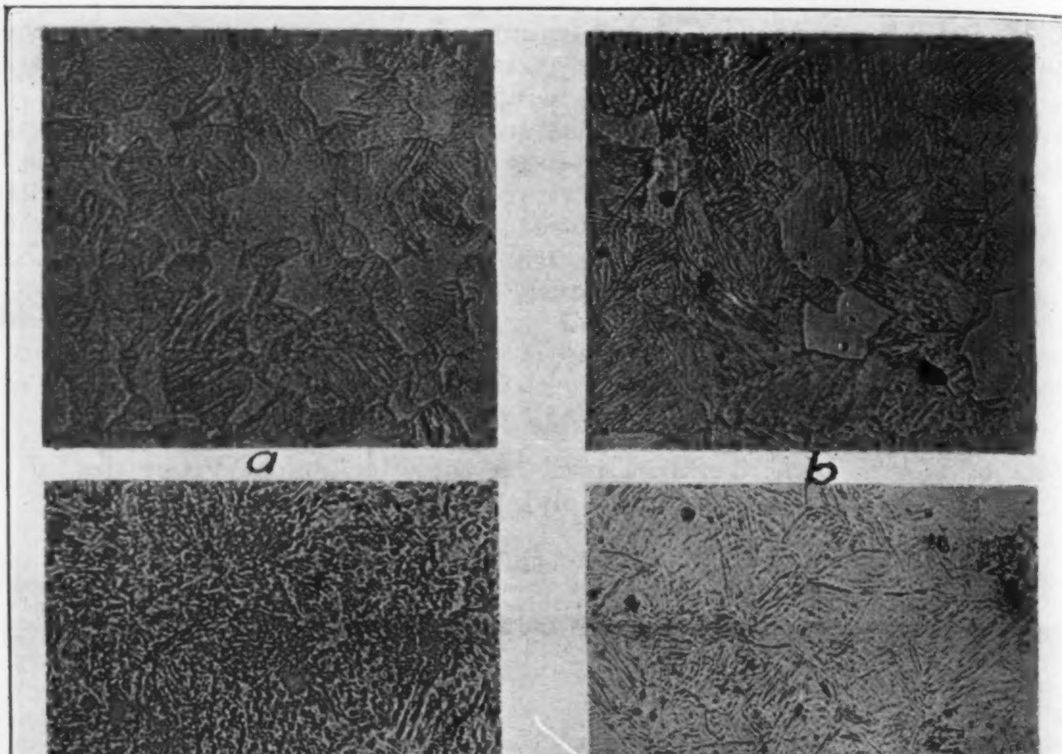


Fig. 8—Structures of a carbon-molybdenum steel quenched in different media from various temperatures with and without preliminary normalizing. X 500. Etched with 2 per cent nitric acid in alcohol. *a.* Oil quenched from 830 degrees Cent. *b.* Water quenched from 830 degrees Cent. *c.* Oil quenched from 910 degrees Cent. *d.* Water quenched from 910 degrees Cent. *e.* Air cooled from 910 degrees Cent. then oil quenched from 830 degrees Cent. *f.* Air cooled from 910 degrees Cent. then water quenched from 830 degrees Cent.

and then water quenched, the structure obtained is again troosto-sorbite but the Brinell hardness is only about 196. The structure shown in Fig. 13*e* is probably equivalent to sorbitic-pearlite as the steel has

been quenched from a temperature below the largest part of the split Ar_1 transformation and is quite soft.

Let it be assumed for the moment that Swinden's statements, to the effect that the lowering temperature "marks a change in state of the molybdenum, or iron-molybdenum compound, in iron and the separation of the carbide is delayed until the 'low' point temperature is reached," are correct. A molybdenum change might readily account for the lower hardness obtained in samples water quenched from 1000 than

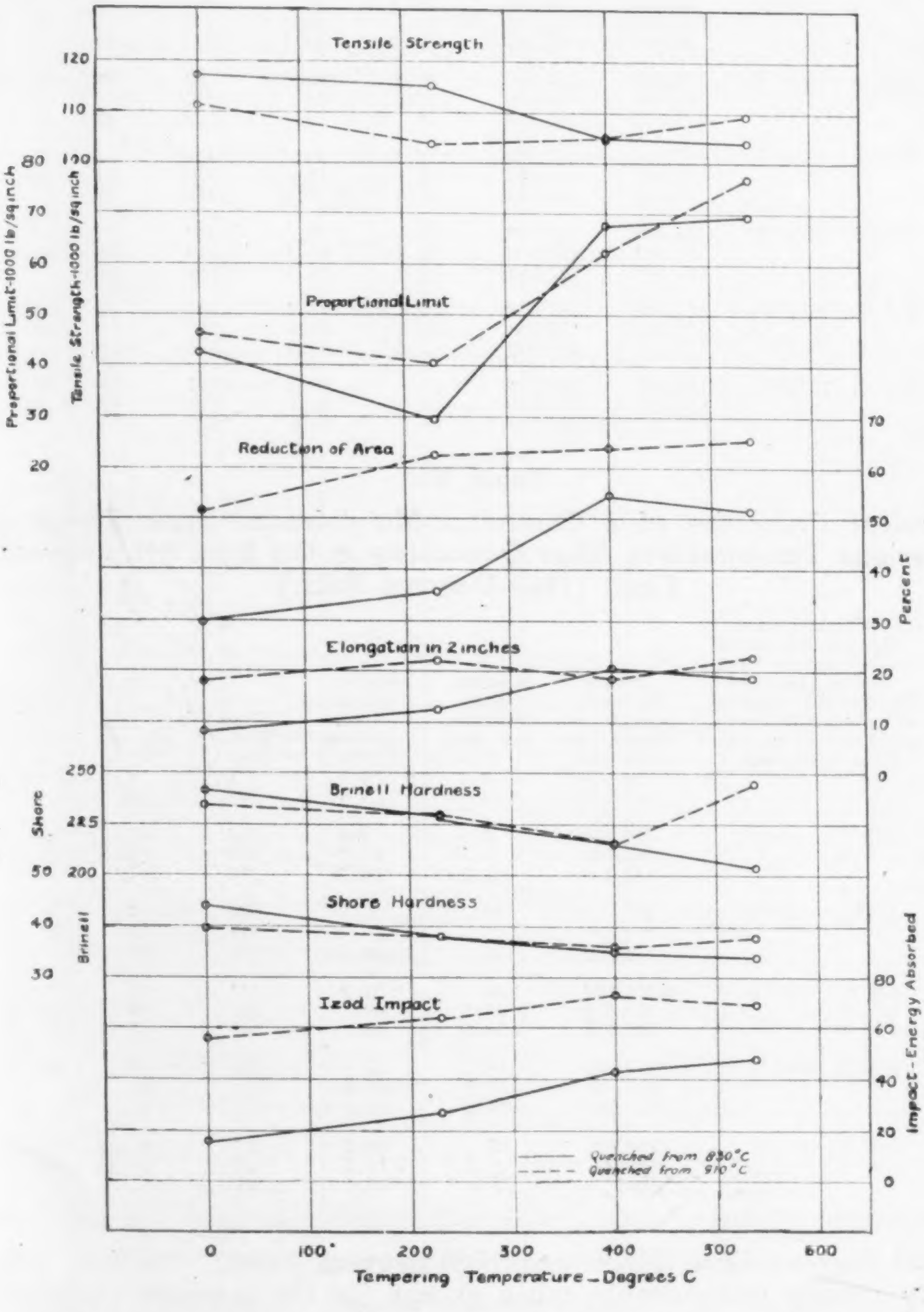


Fig. 9—Mechanical properties of a carbon-molybdenum steel tempered at various temperatures after oil quenching from either 830 degrees Cent. (1525 degrees Fahr.) or 910 degrees Cent. (1670 degrees Fahr.)

Table XI

Effect of Different Quenching Temperatures on the Mechanical Properties of a Chromium-Molybdenum Steel Oil Quenched and Tempered at About 540 Degrees Cent. (1000 Degrees Fahr.)

Number	Treatment—Heated 30 minutes at temperatures designated and oil quenched. Tempered 30 min. at 538°C.		Proportional Limit, pounds per square inch	Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness—Brinell	Hardness—Shore	Izod Impact (Round) foot-pound
29	760°C.	1400°F.	63,500	101,200	23.5	62	226	30	80—62—60
31			66,500	103,400	23	62.6	217	32	43—49—54
Average			65,000	102,300	23.2	62.3	222	31	58
33	815°C.	1500°F.	140,000	167,900	16.5	60	332	46	43—41—43
35			125,500	158,800	15.5	58	321	51	41—45—42
Average			132,750	163,350	16	59	327	49	42
7	845°C.	1550°F.	147,000	165,500	16.5	59.1	364	56	45—45—48
37			140,000	166,800	15	58.6	364	56	43—41—47
Average			143,500	166,150	15.8	58.8	364	56	45
5	885°C.	1625°F.	136,000	163,500	16	58.3	340	55	43—40—45
39			136,000	159,000	15.5	58.3	340	53	40—38—44
Average			136,000	161,250	15.8	58.3	340	54	42
47	915°C.	1675°F.	123,000	161,200	15.5	57.2	321	52	39—46—46
41			157,000	170,200	15.5	58.6	321	50	40—41—44
Average			137,000	165,700	15.5	57.9	321	51	43
71	955°C.	1750°F.	135,000	161,000	15	59.1	302	51	38—43—43
43			134,500	161,300	14	58.1	302	49	41—44—47
Average			134,750	161,150	14.5	58.6	302	50	43

Table XII

Mechanical Properties of a Chromium-Molybdenum Steel Tempered at Various Temperatures After Quenching in Oil from 845 Degrees Cent. (1550 Degrees Fahr.)

Number	Treatment—Heated 30 minutes at 843 degrees Cent. and oil quenched. Tempered 30 minutes at temperatures designated and oil quenched		Tensile Strength, pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent	Hardness—Brinell	Hardness—Shore	Izod Impact (Round) foot-pound
45	(Not tempered)		178,000	4.5	7.9	357	51	9—12—12
49			184,500	3.5	3.9	418	54	8— 9— 9
Average			181,250	4	5.9	385	53	10
51	205°C.	400°F.	187,300	6	9.5	364	63	9—12—13
53			186,700	7.5	10.8	418	58	12—13—15
Average			187,000	6.8	10.2	391	61	12
55	425°C.	800°F.	168,200	10	36.6	364	59	19—18—19
57			185,600	..	..	387	57	15—16—16
Average			176,900	10	36.6	376	58	17
59	650°C.	1200°F.	124,100	20	61.9	252	42	59—65—67
61			126,300	21.5	64	269	44	59—60—66
Average			125,200	20.8	63	261	43	63
63	705°C.	1300°F.	117,400	19	67.1	255	40	68—74—75
3			116,800	21.5	67.4	255	44	
Average			117,100	20.2	67.2	255	42	72
65	760°C.	1400°F.	100,000	22	68.7	217	36	94—95—96
1			102,700	25.5	70.5	228	34	90—95—95
Average			101,350	23.8	69.6	223	35	94

from 960 degrees Cent. (1830 and 1760 degrees Fahr.). In fact, this is the only readily recognizable cause except for the possible contributing effect of chromium. That this latter element is wholly responsible for the observed changes appears improbable in view of the relatively small

proportion contained in the steel which likewise is low in carbon. It also appears doubtful that chromium contributes very largely to these changes in view of the similarity of the effects observed in the carbon molybdenum steel.

In slowly cooling from 960 degrees Cent. (1760 degrees Fahr.) the full lowering of Ar_1 is not obtained, as shown in Fig. 12, so that the carbide separation may be considered to take place at the upper and nearly normal point, 660 degrees Cent. (1220 degrees Fahr.). In cooling slowly from 960 to 715 degrees Cent. (1760 to 1320 degrees Fahr.) before immersing in water, the quenching temperature may therefore be considered to be about 55 degrees Cent. (100 degrees Fahr.) above the carbide release and under such conditions the eutectoid appears as

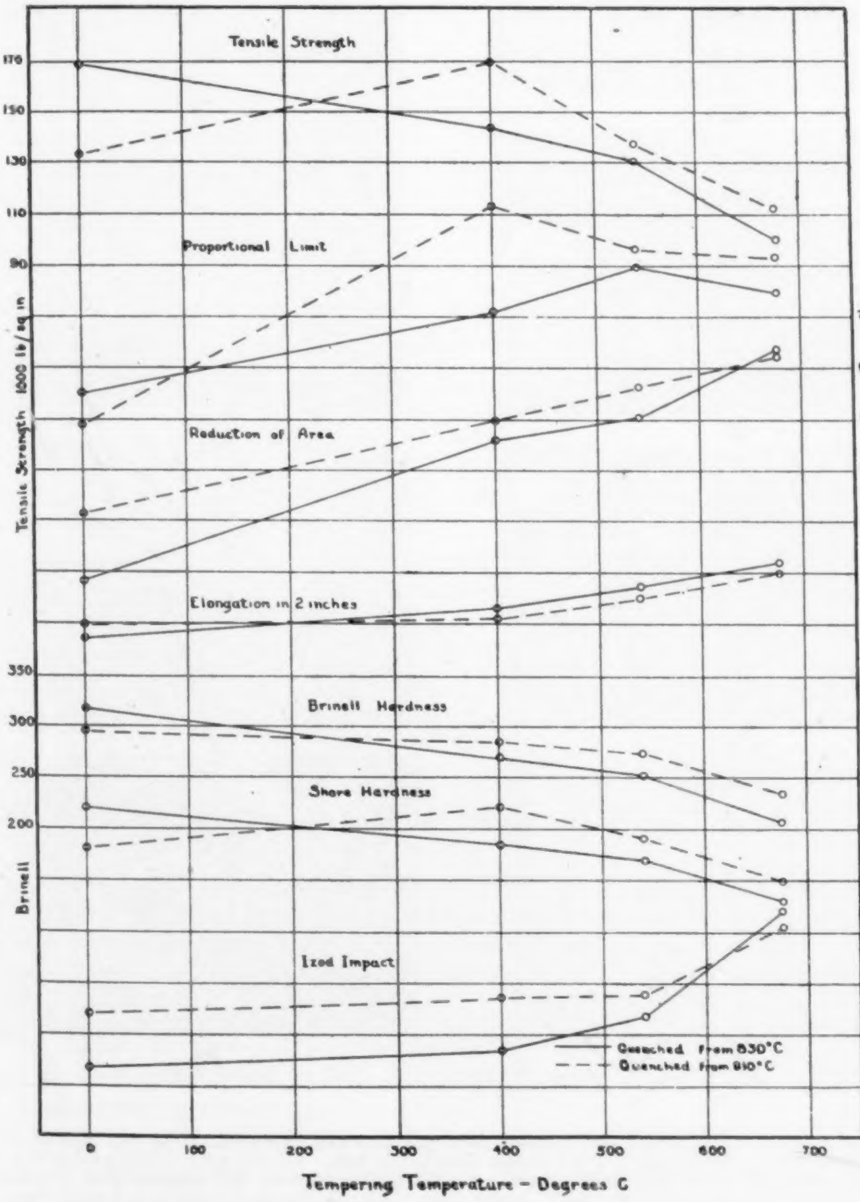


Fig. 10—Mechanical properties of a carbon-molybdenum steel tempered at various temperatures after water quenching from either 830 degrees Cent. (1525 degrees Fahr.) or 910 degrees Cent. (1670 degrees Fahr.)

troosto-sorbite. In cooling from 1000 degrees Cent. (1830 degrees Fahr.) the normal Ar_1 has been largely lowered and a well defined thermal effect is obtained at about 480 degrees Cent. (895 degrees Fahr.). Thus when the steel is cooled to 715 degrees Cent. (1320 degrees Fahr.) before immersing in water, the range of separation of the largest part of the carbide has been exceeded by about 235 degrees

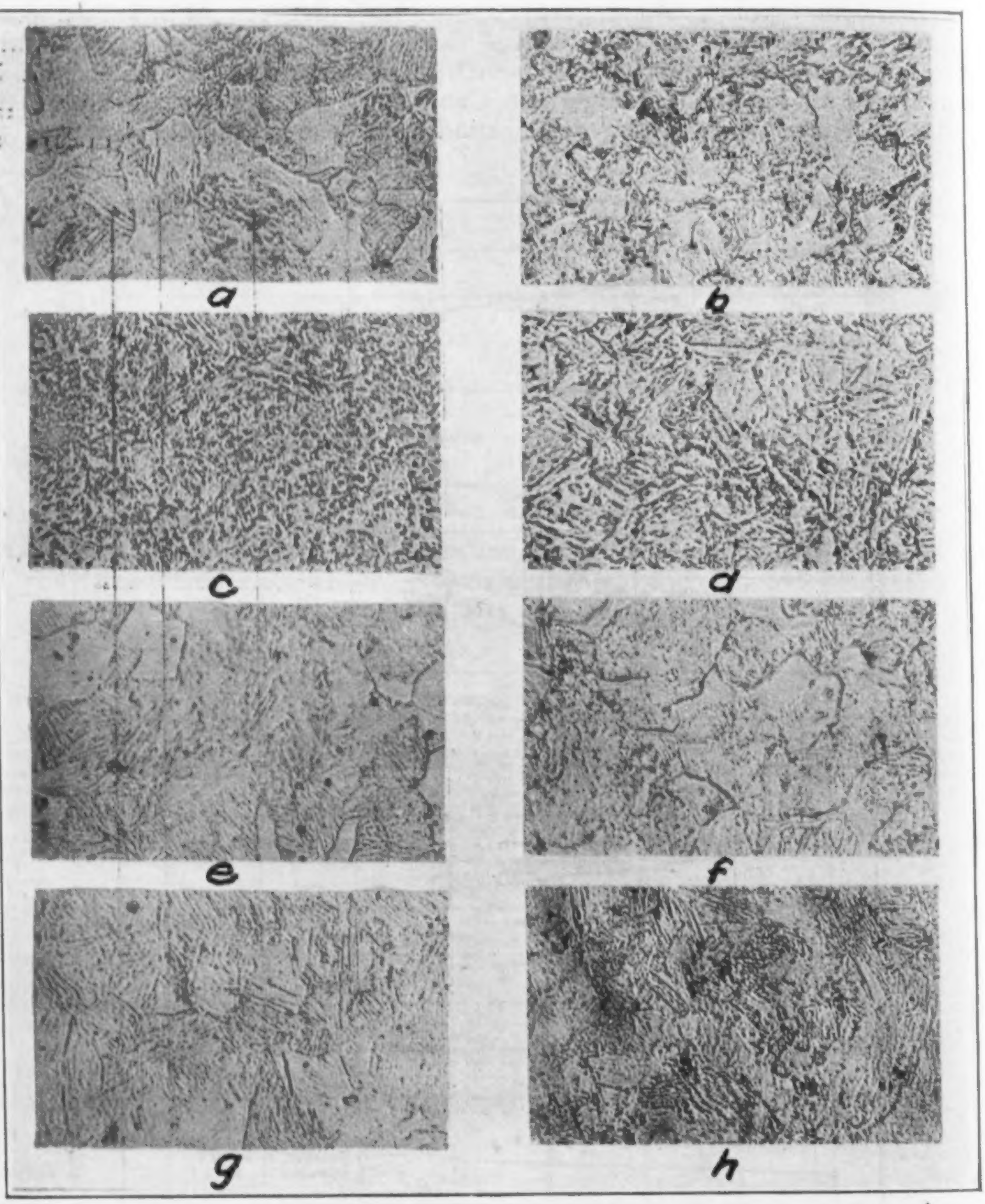


Fig. 11—Structures of a carbon-molybdenum steel oil or water quenched from 830 degrees Cent. or 910 degrees Cent. and tempered at different temperatures. X 500. Etched with 2 per cent nitric acid in alcohol. *a.* Oil quenched from 830 degrees Cent. *b.* Oil quenched from 830 degrees Cent.; tempered at 540 degrees Cent. *c.* Oil quenched from 910 degrees Cent. *d.* Oil quenched from 910 degrees Cent.; tempered at 540 degrees Cent. *e.* Water quenched from 830 degrees Cent. *f.* Water quenched from 830 degrees Cent.; tempered at 675 degrees Cent. *g.* Water quenched from 910 degrees Cent. *h.* Water quenched from 910 degrees Cent.; tempered at 675 degrees Cent.

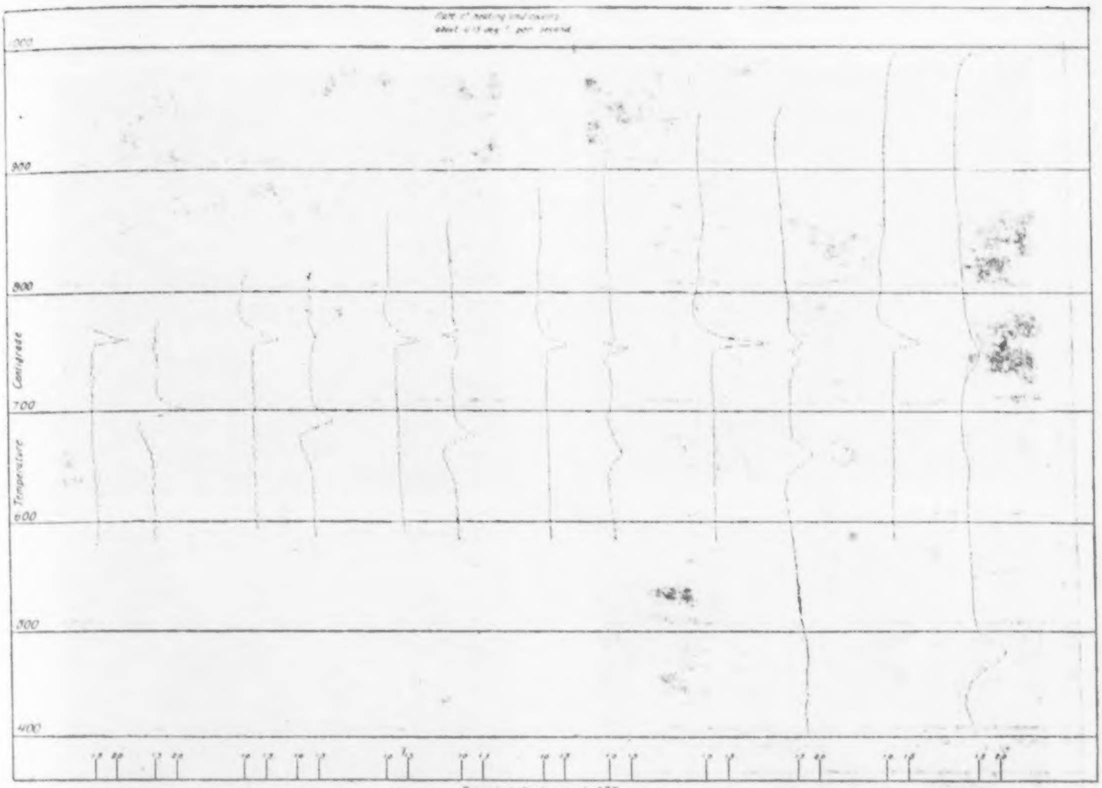


Fig. 12—Inverse-rate heating and cooling curves showing effect of maximum temperature of heating on the transformations of a chromium molybdenum steel

Cent. (345 degrees Fahr.) and martensite is produced[26]. However, on account of the assumed change in molybdenum attended by a lowered Ar_1 transformation, the hardness of the steel decreases, as shown by the samples quenched in water from 960 and 1000 degrees Cent. (1760 and 1830 degrees Fahr.), or conversely about the same hardness is obtained in the troostitic steel which has been heated to a maximum temperature of 960 degrees Cent. (1760 degrees Fahr.) as is observed in the alloy taken to 1000 degrees Cent. (1830 degrees Fahr.) which shows a less complete transition of the eutectoid to stable form.

The low Brinell hardness of the steel, when slowly cooled from 1000 to 590 degrees Cent. (1830 to 1095 degrees Fahr.) before water quenching, may be due to a combination of causes, as follows: (a) The molybdenum change previously mentioned which results in a softening of the steel; (b) the incomplete lowering of Ar_1 which begins at the upper point of the split transformation but is sufficiently retarded so that the largest part of the carbide separation takes place at the "low" point temperature. This means less carbide in solution in the quenched metal and a somewhat softer steel; (c) the suppression of the "low" point change is not as complete when quenching from a temperature only 110 degrees Cent. (200 degrees Fahr.) above this change as it is from higher temperatures.

While this line of reasoning cannot be accepted in the light of a complete explanation as it is based on assumptions which have already

26. The higher the temperature, within limits, of heating the more rapidly does steel of constant mass pass through the transformations and the more completely is the transformation prevented. See also footnote 5.

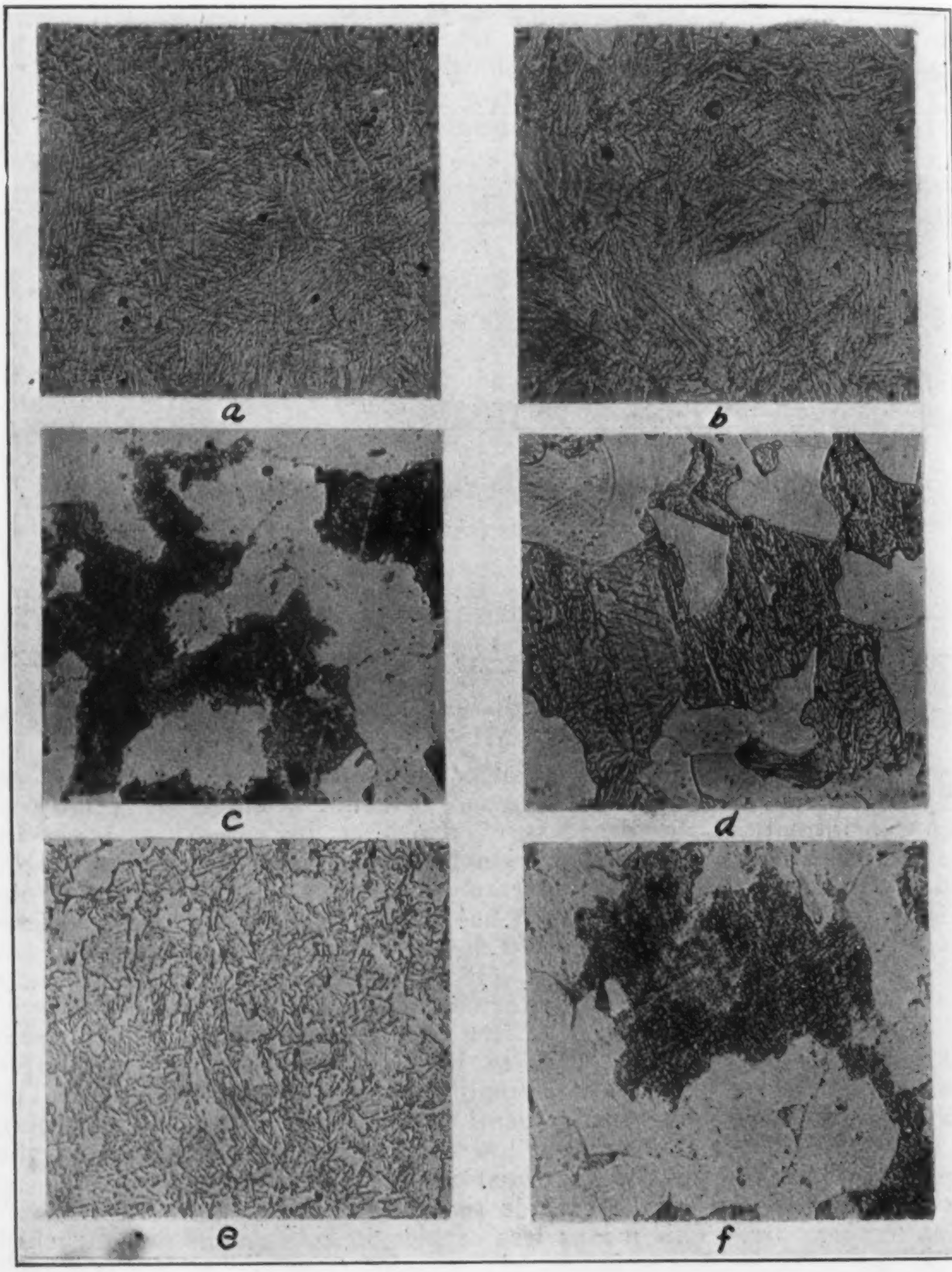


Fig. 13—Structures and hardness of a chromium-molybdenum steel heated to 960 or 1000 degrees Cent. and slowly cooled to different temperatures before water quenching. X 500. Etched with 2 per cent nitric acid in alcohol. *a.* Heated to 960 degrees Cent. and water quenched. Brinell 495. *b.* Heated to 1000 degrees Cent. and water quenched. Brinell 477. *c.* Heated to 960 degrees Cent., furnace cooled to 715 degrees Cent. and water quenched. Brinell 340. *d.* Heated to 1000 degrees Cent., furnace cooled to 715 degrees Cent. and water quenched. Brinell 321. *e.* Heated to 960 degrees Cent., furnace cooled to 590 degrees Cent. and water quenched. Brinell 196. *f.* Heated to 1000 degrees Cent., furnace cooled to 590 degrees Cent. and water quenched. Brinell 196.

been stated, it is interesting to note that the chromium-molybdenum steel shows a tendency to "soften" when high quenching temperatures are used as does the carbon-molybdenum steel considered at the beginning of this report but this change is produced at higher temperatures in the case of the chromium-molybdenum steel containing the lowest proportion of molybdenum.

A decrease in the limit of proportionality in tensile tests and lower impact values, as shown in Fig. 14 and Table X, are obtained when the temperature from which the steel is cooled in air is raised from 780 to 845 degrees Cent. (1450 to 1550 degrees Fahr.). Liebig[27] reported a

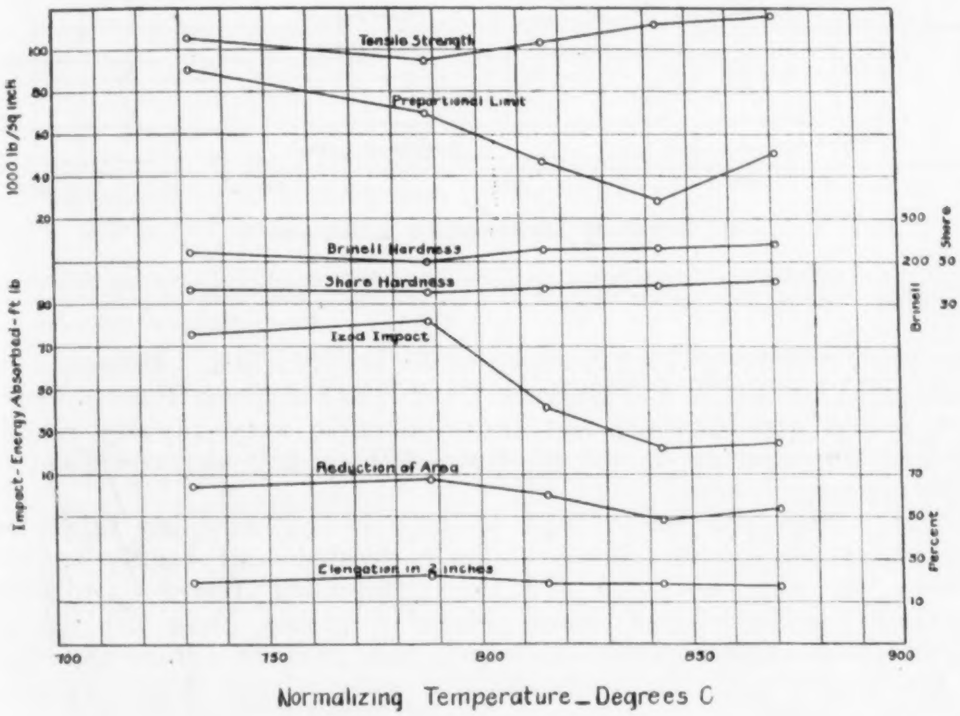


Fig. 14—Effect of varying normalizing temperatures on the mechanical properties of a chromium-molybdenum steel

similar decrease in yield point for the same type of steel containing slightly higher carbon, 0.39 per cent, when the annealing temperature was increased from 760 to 785 degrees Cent. (1400 to 1450 degrees Fahr.), whereas a carbon-chromium steel without molybdenum did not behave similarly. These changes may, as in previous instances, be explained by a molybdenum change.

In Fig. 15 and 16 and Tables XI and XII are shown respectively the effects of varying temperatures in oil hardening steel subsequently tempered at about 540 degrees Cent. (1000 degrees Fahr.) and the effects of tempering at different temperatures on the mechanical properties of the alloy first quenched in oil from 845 degrees Cent. (1550 degrees Fahr.). No extended discussion is required as these data confirm the wide quenching range in which the steel may be hardened in oil without materially altering the tensile or impact properties and the general resistance to decrease in strength of the hardened steel by tem-

27. J. O. Liebig: "A Brief Record of Results of the Annealing of a Chromium-Molybdenum and a Chromium Steel." Journ. Amer. Steel Treaters Soc., Dec., 1919, p. 168.

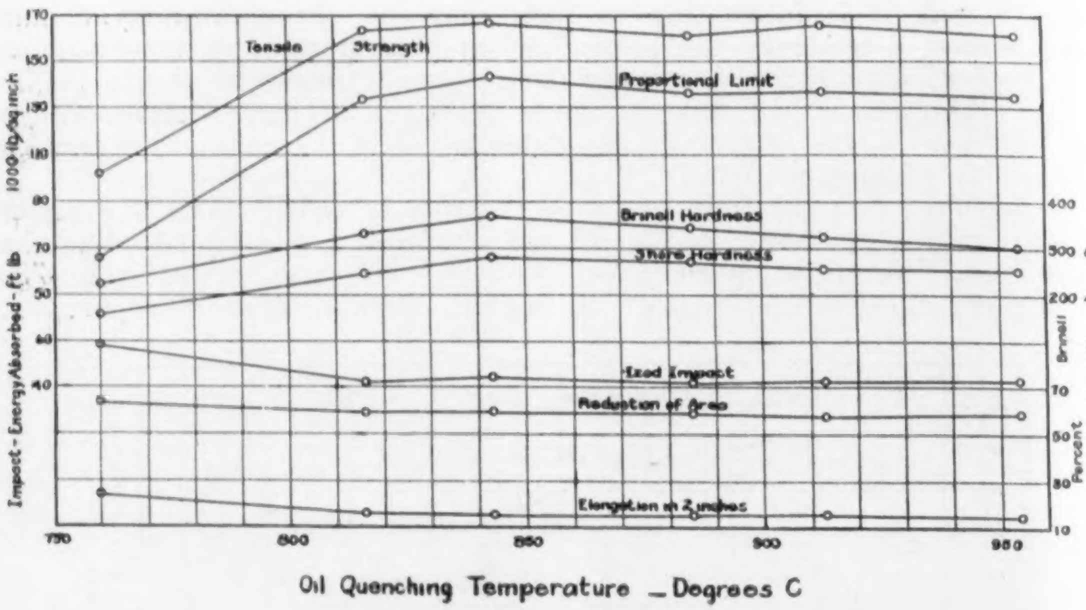


Fig. 15—Effect of different quenching temperatures on the mechanical properties of chromium-molybdenum steel subsequently oil quenched and tempered at about 540 degrees Cent. (1000 degrees Fahr.)

pering until relatively high temperatures are reached. However, when tempering at or below 430 degrees Cent. (800 degrees Fahr.) very low impact values are obtained but these increase very rapidly when the tempering temperature is raised from 430 to 650 degrees Cent. (800 to 1200 degrees Fahr.).

Microphotographs reproduced in Fig. 17 for samples subjected to various heat treatments show a finely divided and highly emulsified structure. In Fig. 17*d* and 17*e* the precipitated ferrite is distributed throughout the matrix in more irregular grains than are generally found in plain carbon steels. In fact, the lack of sharp and regular grain boundaries and the finely divided state of the matrix, especially in Fig. 17*e*, suggests a very strong and tough metal.

The important features determined by the tests previously described may be summarized as follows:

I. Steel containing 0.20 *per cent carbon and* 1 *per cent molybdenum.*

1. For each maximum temperature of heating there is a critical rate of cooling which will lower Ar_1. The higher the initial temperature the slower is the rate of cooling required to produce the lowered transformation but by whatever combination this is produced the position of the "low point" is fixed within a narrow temperature range about 525 degrees Cent. (975 degrees Fahr.). Its suppression can readily be brought about, however, by increasing the rate of cooling.

2. A high temperature transformation is observed slightly above and almost merging with Ar_3 when the steel is cooled from temperatures at or above 960 degrees Cent. (1760 degrees Fahr.) at a rate of temperature change approximating 0.15 degrees Cent. (0.27 degrees Fahr.) per second but is not observed when cooling at much faster rates.

3. Ar_2 is fixed at about 760 degrees Cent. (1400 degrees Fahr.) independent of the maximum temperature of heating or rate at which the steel is cooled.

4. The most suitable temperature from which to harden the steel is in the neighborhood of 910 degrees Cent. (1670 degrees Fahr.). Free ferrite is found after quenching from 830 degrees Cent. (1525 degrees Fahr.) but the observed changes in mechanical properties with rise in quenching temperature within this range cannot be explained by known changes in carbon or iron, by differences in the rate at which the steel passes through the critical ranges resulting from changes in initial temperature of cooling, by unsatisfactory hardening or by the lowered Ar_1 transformation, except as related to a molybdenum change, for they are opposite to the changes found in plain carbon steel under similar conditions of treatment.

5. For the production of definite tensile strength, water quenching is to be preferred on account of the higher proportional limit, ductility, and impact values obtained, and conversely better tensile properties are obtained for a given impact resistance.

6. Raising the quenching temperature from 910 degrees Cent. (1670 degrees F.) to 980 degrees Cent. (1795 degrees Fahr.) does not alter materially the mechanical properties of the steel when subsequently tempered at a relatively high temperature, 540 degrees Cent. (1000 degrees Fahr.).

II. Steel containing 0.27 per cent carbon, 0.9 per cent chromium and 0.5 per cent molybdenum.

7. The Ar_1 transformation is first split and lowered when cooling from 960 to 1000 degrees Cent. (1760 to 1830 degrees Fahr.) at about

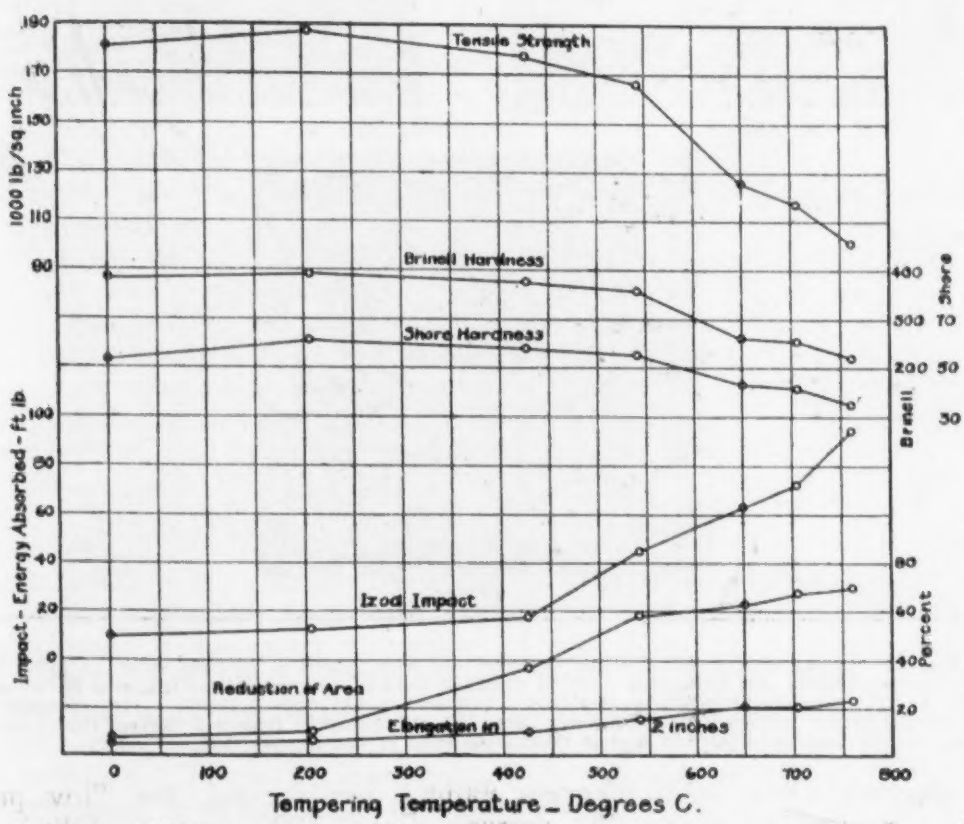


Fig. 16—Mechanical properties of a chromium-molybdenum steel tempered at various temperatures after quenching in oil from 845 degrees Cent. (1550 degrees Fahr.)

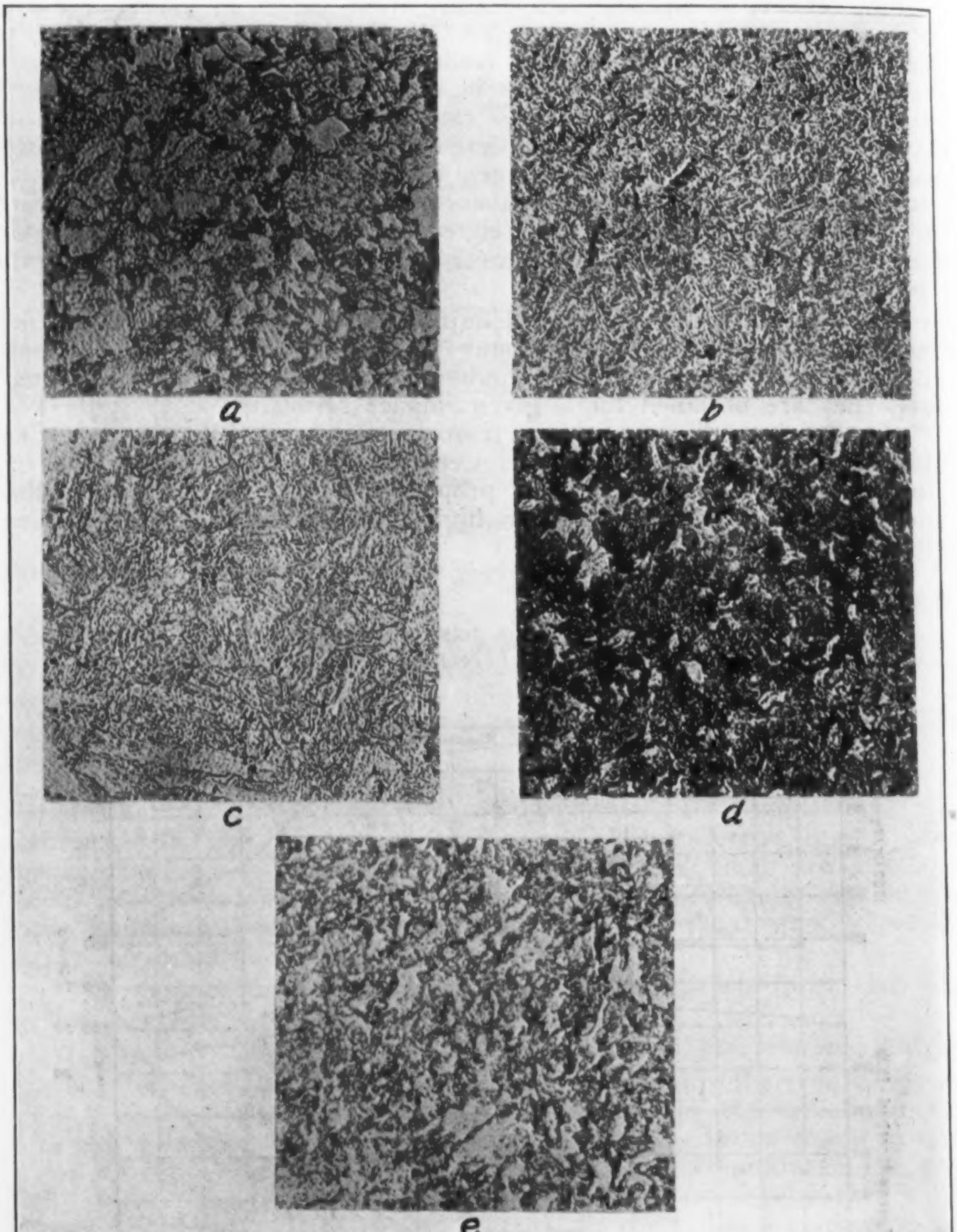


Fig. 17—Structures of a chromium-molybdenum steel heat treated in different ways. X 500. Etched with 2 per cent nitric acid in alcohol. *a*. Oil quenched from 760 degrees Cent.; tempered at 540 degrees Cent. *b*. Oil quenched from 845 degrees Cent.; tempered at 540 degrees Cent. *c*. Oil quenched from 955 degrees Cent.; tempered at 540 degrees Cent. *d*. Oil quenched from 845 degrees Cent.; not tempered. *e*. Oil quenched from 845 degrees Cent.; tempered at 650 degrees Cent.

0.15 degrees Cent. (0.27 degrees Fahr.) per second, the "low point" being observed at about 480 degrees Cent. (895 degrees Fahr.). In water quenching from the highest temperature, a lower hardness is obtained than when similarly cooling from 960 degrees Cent. (1760

degrees Fahr.). In this respect the chromium-molybdenum steel behaves similarly to steel containing 0.20 per cent carbon and 1 per cent molybdenum, except that the observed changes are produced from higher temperatures.

8. In normalizing the chromium-molybdenum steel a low limit of proportionality and impact resistance are obtained when using temperatures between about 780 to 845 degrees Cent. (1450 to 1550 degrees Fahr.).

9. The fact that no material changes in tensile or impact properties are produced by oil quenching the chromium-molybdenum steel from a wide range of temperatures when subsequently tempered at 540 degrees Cent. (1000 degrees Fahr.) has been confirmed. Likewise confirmation of the resistance of the oil hardened steel to decrease in strength by tempering has been obtained. To increase the low impact values of the hardened steel, a tempering temperature in the neighborhood of 650 degrees Cent. (1200 degrees Fahr.) is required.

Acknowledgment is made to W. G. Johnson, assistant physicist, and to T. E. Hamill, laboratory apprentice, who carried out the greater part of the routine work in connection with the described tests.

Discussion of Mr. French's Paper

MR. MERTEN: I would like to ask the speaker why he operated with a low carbon material and chrome molybdenum steel when most of that in use is around 0.40 per cent?

MR. FRENCH: When we planned a series of tests we wanted material in the neighborhood of 0.35 or 0.40 per cent carbon but the heat we obtained contained lower carbon. What we were particularly interested in was the effect of heat treatment, not so much in getting the carbon for a given molybdenum content. We were not interested primarily in comparing the molybdenum steel with other alloy steels as a good deal of information has been published along that line. What we were interested in was the treatment and the steel was put through various thermal manipulations with that in mind.

MR. JOHNSON: I would like to ask the speaker the depth of the slot in the impact specimens?

MR. FRENCH: For the carbon-molybdenum steel a square 45-degree, triple-notched Izod specimen was used having a notch depth of 0.019 inches. For the chrome-molybdenum steel a round impact specimen was employed with a similar type of notch.

MR. SCOTT: Does molybdenum alloy with ferrite or does it form carbide?

MR. FRENCH: How much molybdenum?

MR. SCOTT: The ranges you were talking of.

MR. FRENCH: It has been assumed by Swinden and others that molybdenum combines first with the ferrite. That point is in dispute. I don't know. The exact condition of molybdenum in steels has not been settled. The most comprehensive study in recent years, I believe, has been the work by Swinden. He considers that molybdenum is distributed throughout the ferrite, somewhat in the nature of a solid colloidal solution. These present tests were not conducted with the idea of determining in what state the molybdenum existed in the steel, but as explained previously, they have been examined in the light of Swinden's work, to see whether his explanations would fit in with the results

obtained and in general they seem to do so. That does not mean that Swinden's hypothesis is the correct one or that it is the final answer. Molybdenum is considered as a carbide-forming element, when present in sufficient proportion, but with low carbon and less than 1 per cent molybdenum, we don't find any evidence of special carbides under the microscope when using ordinary etching reagents and a magnification of 500 or 1000 diameters.

MR. VANNICK: My attention has been called to some chrome molybdenum steels containing about 0.5 per cent of molybdenum, in which etching was done with concentrated nitric acid, about 50 per cent nitric acid and water, in the pearlite steels. In that steel the peculiar feature was the yellow stains that appeared over the pearlitic areas, which we took to be oxide in the molybdenum. I could not say whether that came from the ferrite in the pearlite or whether it came from the carbide in the pearlite, but at any rate it appeared over the pearlitic areas and we were not particularly interested in it at the time, but if it is worth anything it probably will be interesting for some one to try that process and locate, if possible, the position of molybdenum in the structure.

HEAT TREATMENT OF LARGE FORGINGS BY OIL, GAS AND ELECTRICITY

By W. E. McGahey

THE term "large forging" is very broad and may mean any class of forging having sufficient weight to be termed a large forging. Many so-called large forgings are made for commercial purposes which require practically no actual heat treatment other than an anneal to pass the specifications under which the forging is made. As this class of work does not require a great deal of attention and accuracy in heat treatment, being gen-

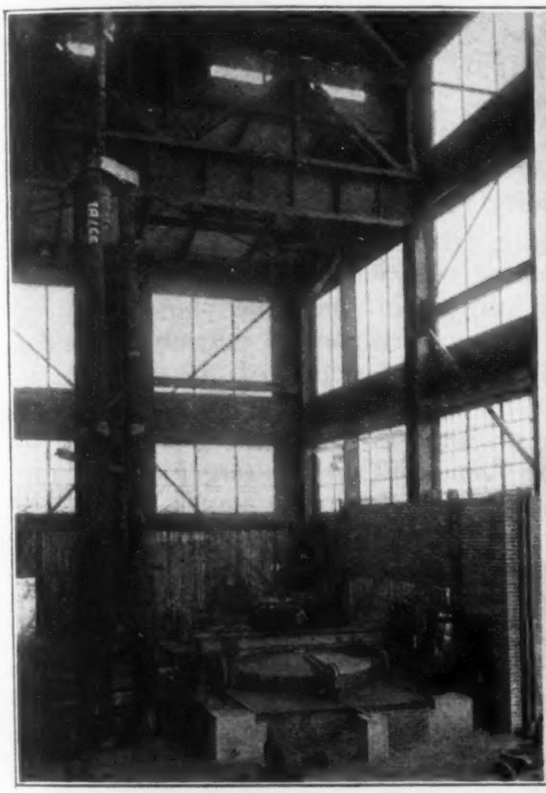


Fig. 1—Three 30-foot hollow forgings having a diminishing wall thickness which have just been drawn from the 36-foot electric furnace at the right.

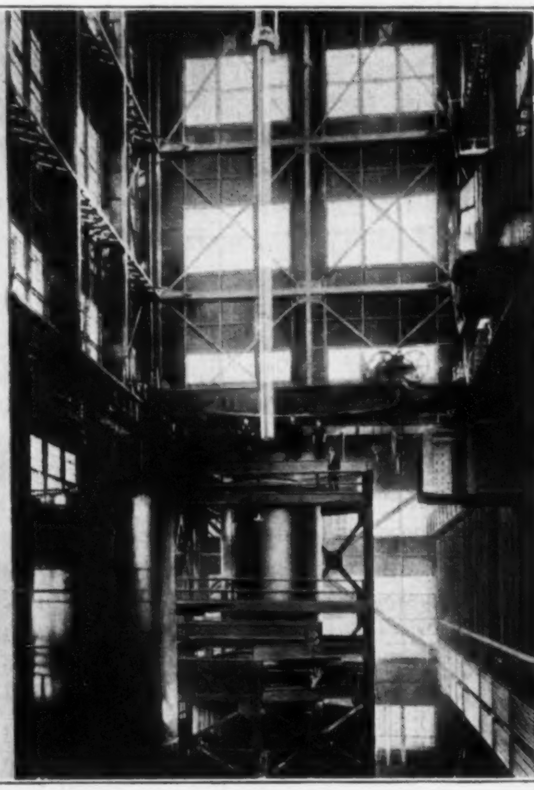


Fig. 2—Hollow ship shaft suspended over a 70-foot furnace. Courtesy Allis-Chalmers Mfg. Co., Milwaukee, Wis.

erally handled in the forged condition, either oil, gas or electricity may be used with equal satisfaction as heating mediums. Which is the most practical and economical fuel depends primarily upon the locality. Oil and gas are more generally used in preference to electricity on account of the high installation cost of the latter. The term "large forging" in this case more particularly applies to large hollow forgings of a nature that requires more extensive heat treatment to pass some high specification of physical quality.

There is really but one satisfactory way of treating a forging of this type, this being to handle it in a vertical position, which is accomplished by the use of the cylindrical pit furnace. To meet this condition the forging is rough machined, (and rough bored in cases, where the inside diameter

A paper presented before the Indianapolis Convention. The author, Wm. E. McGahey, formerly foreman, heat treating large guns, U. S. N. Ordnance plant, Charleston, W. Va.

is too small for hollow forging) before heat treating, in order to obtain mechanical uniformity in handling and uniformity of cross section for treatment. The main thing in the heat treating of large hollow forgings of this type, is to get absolute temperature control and uniformity of temperature throughout the whole charge of metal. To accomplish this is not an easy problem as the forging may be very long, small in diameter and having a comparatively thin wall. Even the wall thickness varies in some cases, being very much greater at one end than the other, making it all the more difficult to treat. Forgings having this different area of cross section are generally quenched from a constant temperature somewhere above the upper critical range and the draw temperature is split, gradually increasing from the heavy end to the lighter.

Serious defects may result from lack of uniformity in heating, such as cracks, hard spots or soft spots. Hard or soft spots are something that may never be detected while in the process of manufacture, but may cause considerable damage in service. It may be true that such cases do not very often present themselves, but it is the writer's desire to bring these points out to illustrate the importance of uniformity in heating.

Uniformity is largely dependent upon temperature control, the time element also entering. The method of control is practically the same for either oil or gas; each burner or multiple of burners in the same plane having to be individually operated, which makes temperature control entirely dependent upon the skill of the operator. As the size and depth of the furnace increases, difficulty in operating and control also increases. The baffle wall or muffle which is generally used in oil or gas fired furnaces helps the situation a great deal by breaking up the flame and distributing the heat more evenly over a large area but does not guarantee absolute evenness in heating. The electric furnace is entirely different in its method of control, being automatically operated and controlled in zones. Each zone may be made to yield the same temperature as the surrounding zones or a different temperature, thereby making it possible to graduate the temperature accurately from one end of a long forging to the other. The construction is such that the heating element in each zone is evenly distributed around the interior wall which causes the heat liberated to be the same at any point within the zone. If all the zones are operated at the same temperature then the heat liberated at any point within the furnace will be the same.

In using oil or gas, the burners must be adjusted correctly to give the proper mixture of the fuel and air for complete combustion without excess air. Excess air reduces the effective heating efficiency as a certain per cent of the heat liberated is taken to heat the excess air. Excess air also causes a great deal of scale on the surface of the forging which is not desirable. The only air to be considered when dealing with the heating efficiency of an electric furnace is the air that fills the space between the charge and the furnace wall. This is not of material effect as the furnace is tightly sealed to prevent any other air from entering. No openings are necessary other than observation vents which are kept tightly closed when not in actual use. Comparatively little heat is lost in heating the air, most of the heat produced being effective by radiation. The average effective heating efficiency of an electric furnace, of this cylindrical pit type, ranges from 70 to 80 per cent.

It might be interesting to note that the life of the electric furnace of this type is as much as twice and sometimes thrice that of either oil or gas,

By life is meant the comparative time two furnaces will last without any major repairs, when started at the same time and operated under the same conditions. In the electric furnace there is no high combustion temperature or blast of burning gases, impinging on the walls, to cause the lining or furnace wall to give away. There are numerous other minor advantages derived from the use of electricity as a heating medium in the heat treatment of large hollow forgings which it is unnecessary to discuss, such as cleanliness, lack of noise, lack of necessary storage for fuel, lack of necessity for extensive piping and blowers, etc., as these are familiar features.

Taking everything into consideration, the writer believes that you will agree with him that even though the electric furnace may be more costly to build, it has offsetting advantages in its favor, these being decreased maintenance cost of upkeep and simpler and more definite control which gives greater uniformity in heat treatment. This great uniformity is more economical in the end as a greater per cent of forgings will be accepted on a single heat treatment, thereby saving the cost of additional heat treatment.

THE EFFICACY OF ANNEALING OVERSTRAINED STEEL

By Irving H. Cowdrey

WHY is it that anchor chains, hooks, hoisting tackle and many other iron and steel parts are periodically annealed by careful contractors and engineers? To what extent is this treatment successful in producing the expected restoration of the original properties of the parts in question? These two questions must have suggested themselves many times to the intelligent man who has been brought into contact with the commercial heat treatment plant or who has been called upon to make use of the various parts commonly subjected to the treatment under consideration. Numerous answers have been tendered in the past; some of them contain a generous portion of truth, and some, in the light of modern knowledge and ideas, are quite erroneous.

In the earlier days when steel was held to be fit for cutlery and tools alone, and nothing but wrought iron would be for a moment considered as a material for structural members, it is not at all surprising to find queer ideas concerning the constitution of these different though related products. The blacksmith nicked the iron bar, broke it across the anvil's edge and noted the stringy ragged fracture like a piece of tough rickory. Hence he held that wrought iron was essentially a fibrous material. When the piece of steel rod from which he was to forge a chisel or other like implement was broken, resulting in shiny sparking surface of coarser or finer grain he said the steel was crystalline. When the chain link parted or the hook snapped, perhaps on a cold frosty morning, showing a bright sparkling, granular texture, what was more natural than to say that the iron, which he supposed to be a fibrous metal, had by some mysterious process, crystallized. We find then such terms as cold crystallization, fatigue etc., constantly appearing in the older literature on the subject. The advent of the microscope into the field of engineering made it possible to explain much, which had before been veiled in mystery, concerning the behavior of metals both under stress and heat treatment.

The first of the questions, has been answered at least by inference by several of the modern writers,* who will be freely drawn upon in the following discussion. The second question finds its answer in the results of certain tests which will be outlined and discussed later on. In order that the reader may have a clear understanding of the problem under discussion, the writer will take the liberty to survey the most modern conception of the structure of iron and steel and note the effects brought about by overstrain.

No one today questions the fact that metals are made up of microscopic granules. The size, shape and constitution of these granules depends mainly upon two factors: first, the chemical constituents of the material: second, the physical treatment which it has received. Under the heading of physical treatment the writer would include, hot working above critical range, cold working below critical range, and the heat treatment. These granules are composed of crystalline material under all circum-

*Materials of Construction, by G. B. Upton.
Materials of Construction, by A. P. Mills.
Steel and Its Heat Treatment, by D. K. Bullens .

A paper presented before the Indianapolis Convention. The author Irving H. Cowdrey is Assistant Professor Testing Materials, Massachusetts Institute of Technology, Cambridge, Mass.

stances. Their boundaries are well defined and commonly are formed by a series of planes. Between the granules, or as it is frequently expressed, at the grain boundaries and completely surrounding the grains, there exists a very thin layer of noncrystalline, or amorphous material, sometimes referred to as the amorphous cement. This amorphous material may under some circumstances be of a chemical composition identical with the grains which it embraces. Its physical properties, however, are always quite different from those inherent in the grain. It is always harder, stronger, and less ductile than the corresponding crystalline material, and tends to impart these properties to the entire mass, to a degree more or less in proportion to the magnitude of the quantity present. Under an ordinary circumstances it represents but an extremely small portion of the whole mass of metal. In this connection it should be noted that the quantity of this amorphous cement is dependent upon the superficial area of the granules and the smaller the granules the greater will be this total superficial area; hence the greater relatively the quantity of the amor-

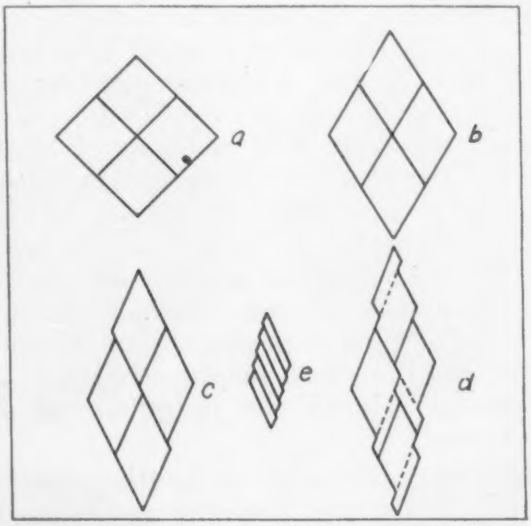


Fig. 1—Diagrammatic illustration showing the manner in which four crystals are probably distorted when subjected to various loads.

phous material. Any cause which tends to reduce the size of the granules will tend to harden and strengthen the metal and generally to render it less ductile, hence more brittle and less resistant to shock, except perhaps with some of the modern alloy steels. With this premise in mind, it will now be in order to consider the effect of severe stresses in metallic members.

Any stress, however slight, will produce distortion in the metal resisting it. This resulting disortion may be of two types; either elastic, from which recovery is complete, or plastic from which there is no recovery, or partaking in part of each type, in which case the recovery will be partial. In order to study these actions in detail let us imagine four adjacent cubical crystals shown in section in Fig. 1a. During the elastic distortion it is held that the granules are deformed but maintain their integrity and mutual positions with no displacement of one granule surface with respect to those adjacent to it, as in Fig 1 b. Upon recovery each granule returns in all senses to its original form, position and condition. Plastic distortion

is the result of either bodily displacement of the granules with actual motion of one bounding surface over the adjacent one, Fig. 1c, or shear within the granules in which one portion slides past that adjoining it. In general both types of displacement occur simultaneously as suggested in Fig. 1d. If the distortion is excessive each granule is likely to shear on a series of parallel planes as is suggested diagramatically in Fig. 1e. These parallel cleavages produce what are known as slip bands in the grains which are admirably shown in the photomicrograph Fig 2a made by Dr. R. S. Williams. Displacements of this nature are permanent and produce what is termed permanent set in the member. The effect produced in metal burnishing and glazing of bearings in service is well known. No practical man will deny the fact that the surface produced under such conditions is different from the body of the metal particularly in that it is appreciably harder. A similar change then might be expected at the surface where sliding occurs, as outlined above. Such change is due to the increase in the quantity of amorphous cement which finds its genesis in the mutual burnishing between the sliding surfaces. Moreover, if internal shear results, a portion of the metal adjacent to the planes of shear is transformed from the crystalline to the amorphous condition. From this it must be concluded that elastic distortion should produce no physical change in a metal, while plastic distortion, due to the increase in the amount of amorphous material, will tend to give greater hardness and while increasing the static tensile strength will nevertheless render the metal more brittle and less resistant to shock. Not only will the above results be produced, but successive abuse in the way of overstrain will yield a cumulative effect. Since the amorphous material is more brittle than the crystalline from which it was formed, fracture under shock will follow the planes in which it is present. The broken surface will then be made up of planes, resulting in a bright sparkling appearance generally characterized as granular. Hence the judgment of the uninformed that the metal has crystallized.

Having thus noted the evil effect of continued overstrain it is logical to attempt its removal if possible. Periodic annealing has for many years been the prescribed remedy. The question may very properly then be raised as to the efficacy of such treatment, and the extent to which metal may be overstrained and still be restored by annealing. While it has been admitted by most engineers that the effect of slight over strain may be in part, if not wholly, removed by annealing, yet there have been a certain number who have held that very excessive distortions produce results which cannot be nullified by such treatment. Moreover many have declared annealing to be completely effective only for the very lowest carbon steels. To prove or disprove this stand, a set of tests * were lately conducted at the suggestion of the writer in the testing materials laboratory of the Massachusetts Institute of Technology in accordance with the following schedule.

The material selected was a 0.20 per cent carbon steel with the normal content of silicon, manganese, sulphur and phosphorus. This was purchased as hot rolled steel 1½-inches in diameter and about 7 feet long. From this tensile test specimens were fabricated to determine its physical properties as received and also after careful annealing. The remainder of the bar was then subjected to torsion, and twisted cold until fracture was

*Mahan and Sloan. M. I. T. thesis 1920.

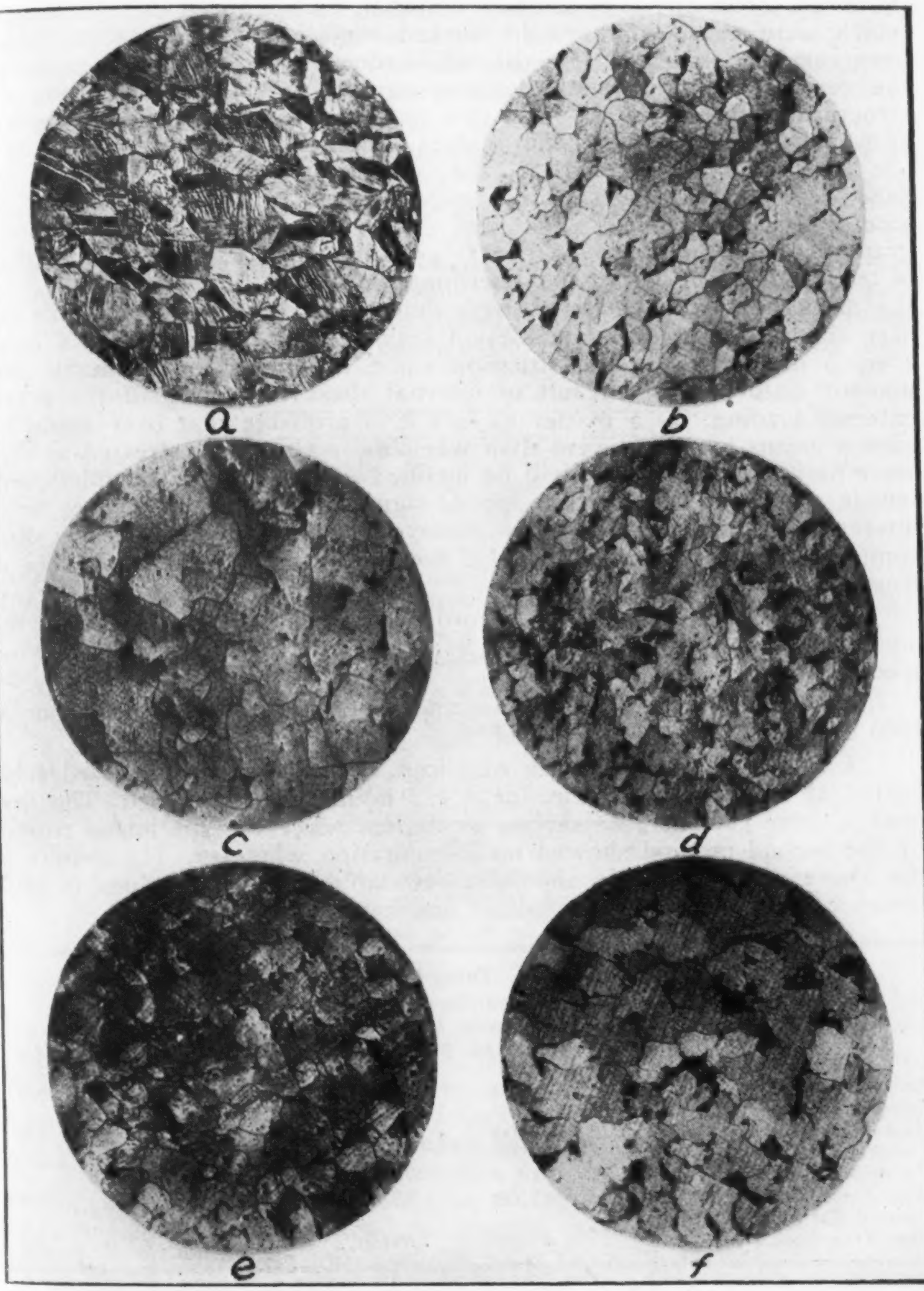


Fig. 2—Photomicrographs showing the structure of specimens subjected to various loads and heat treatments. *a*. Drawn Brass. X 75. *b*. Steel as received. X 100. *c*. Steel as Received plus Heat Treatment I. X 100. *d*. Steel after twisting. X 100. *e*. Steel Twisted plus Heat Treatment I. X 100. *f*. Steel Twisted plus Heat Treatment II. X 100.

produced. From the over strained material, tensile specimens were taken which were tested in this cold worked condition and also after having been carefully annealed. The Brinell hardness was determined under all the various conditions and photomicrographs were made to study the structure of the metal. At least two specimens were tested in each case and in every instance the values checked admirably. All tensile specimens conformed to the dimensions of the U. S. standard test bar having a 2 inch gage length and a 0.505 inch diameter with threaded ends and were tested in a universal autographic testing machine of 60,000 pounds capacity. Such a method of testing does not permit the determination of the true elastic limit. That the properties of the material were determined under tension while the over strain was produced in torsion may seem paradoxical. Such, however, is not in reality the situation since, according to Upton all permanent distortion is a result of internal shear regardless of the actual external loading. As a matter of fact it is probable that over strain by such a means is more severe than when the specimen is stressed axially, since fissures, if produced, will be inclined to the axis of the subsequent tensile specimen. While of no special significance, it may however be of interest to note that the bar as received, twisted through nearly 16¾ complete turns in a length of 4 1/2 feet or nearly 3¾ turns per foot of length.

The annealing was done in accordance with one of the two following methods which will be designated as Treatment I, and Treatment II respectively.

I. Specimen wrapped in carbon and asbestos, heated for one hour at 1760 degrees Fahr. and air cooled.

II. Specimens packed with cast iron chips in a loosely closed tube, heated at 1760 degrees Fahr. for 1 1/2 hours and air cooled. The first method gave considerable surface oxidation, while the specimens treated by the second method showed no discoloration whatever. The results of the above tests appear in the following tabulation. The values in each instance are the averages of at least duplicate tests.

Table I

Results of Tensile Tests

	Yield Stress pounds per sq. inch	Ultimate Stress pounds per sq. inch	Elong. per cent	Red. Area per cent	Brinell No.
Bar as received	46000	67850	35.7	64.4	131
As received plus Heat Treatment I	40000	68250	33.7	62.5	130
Twisted Bar	86500	95633	15.8	54.3	180
Twisted Bar plus Heat Treatment I	42200	67200	36.5	62.5	128
Twisted Bar plus Heat Treatment II	43150	69450	37.0	62.0	127

The photomicrographs representing the structure of the metal for the various conditions are shown by Fig. 2b, 2c, 2d, 2e, 2f. In the original investigation four photomicrographs were made for each condition of the metal, two on each of two planes, respectively parallel with and perpendicular to the axis of the twisted bar. Each set of two comprised one near the center and one near the edge. As was to be expected, little

change of structure was observed in the center of the bar, since the distortion was almost negligible at that point. The greatest and most significant changes of structure were observed in the longitudinal section near the surface, and it is these photographs only which have been included in this discussion.

The various data will now be analyzed and discussed. Throughout the discussion it should be kept clearly in mind that it is in general impossible to obtain perfect checks in the testing of any material whatever. With very homogeneous steels variations of several percent must be expected even when tests are conducted on adjacent specimens. Hence variations of two or three thousand pounds per square inch in yield stress and ultimate stress and one or two percent in elongation and reduction of area are entirely negligible, within the above limits, then, there

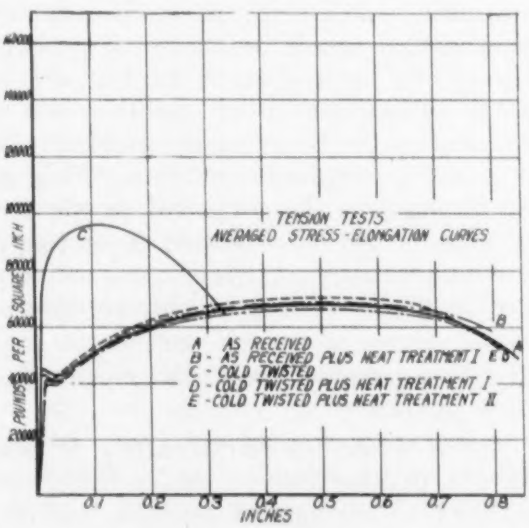


Fig. 3—Autographic Load-Elongation Curves. These curves are reproduced from the charts taken from the testing machine. Curves show the average result for each set of tests.

is perfect agreement between the figures in the first two and last two rows. Among other things this would indicate that the material was very well annealed when purchased. The results recorded in the center row showing properties after cold twisting are of an entirely different order. The yield stress has been doubled (see discussion of the graphs), while the tensile stress and hardness have been increased about one half. On the other hand, the ductility is less than half that evidenced by the normal metal. This difference is entirely in accord with results obtained from tests on cold worked material in general, such as cold rolled steel, extruded metal and wire provided the material is of such dimensions and so fabricated that the effect of cold working has pentrated well into the interior. With the increased hardness and decreased ductility is would seem obvious that the metal is in a state quite unsatisfactory for resistance to shock even though its static strength has been increased. Overstrained hooks, chains and-so-forth, have suffered alteration in their physical properties along just such lines as this, the difference being solely one of degree. As before intimated, the last two rows show that the

original properties have been completely restored by the heat-treatment to which the steel was subjected.

The autographic load-elongation diagrams are reproduced in Fig. 3. In redrawing these diagrams the data for each set have been averaged and are indicated by a single line, to simplify the comparison of the results. In addition, the usual obscuration of the yield point by overstraining is well marked. The sharp jogs, with decrease of resistance on the part of the specimen noted in the original and anealed specimens, corresponds to the sharp and decided drop of the beam usually sought after by the engineer. No such phenomenon marks the yield to the over-strained material necessitating a somewhat arbitrary determination of that value which commonly taken at 1 per cent elongation.

The explanation of these agreements and variations is to be found in the photomicrographs. Fig. 2d and 2c shows a normal granule arrangement of reasonable size without evidence of grain distortion. Here might be expected the usual quantity of amorphous cement hence the normal properties of low carbon steel. In Fig. 2d, marked distortion of the granules appears, indicating both motion on adjacent boundary planes, and the formation of myriads of internal clearage planes with the consequent increase in the amorphous material. This great increase in the cement produces the change in the physical properties noted previously. Fig. 2e and 2f show clearly the readjustment of the granules which has been accompanied by the return of the excess of amorphous cement to its normal crystalline form, resulting in the complete restoration of the original properties.

As a result of the foregoing theory, description and analysis the following conclusions are in order.

1. Overstrain of metal when its temperature is below the transformation range, results in the production of undesirable properties tending to render the metal unfitted to withstand sudden and shock loads.

2. If possible such effects should be eliminated for the safety of those using devices which have been so abused.

3. Proper annealing suffices to completely restore the normal properties of low carbon steel even after the most severe over strain.

ORGANIZING RESEARCH TO MAKE IT PAY DIVIDENDS

By W. P. Woodside

THE foregoing subject upon which it was suggested that I speak demands at the outset a little analysis and definition. There can be no question but that there are hundreds of ways in any business of so carrying out its necessary and peculiar research that the ultimate financial return to the institution is enhanced. The greater or less degree of these increased returns measures only the effectiveness of the methods used. We may, I believe, safely accept the view that research can pay dividends without discussion or further elaboration of the subject. There is no general accord on the relative place a research department shall hold in an organization—no uniformity of opinion as to the proportional amount of funds which should be devoted to its use, and no agreement on the amount and quality of equipment and personnel which should be allotted to it. In some industries, both of a large and small nature, research occupies a relatively important and responsible part —in others, its role is but the smallest if not indeed noticeable by its entire absence. There should be no doubt in view of the present day traditions of business that work of the sort we are discussing has a real, definite and valuable place. It seems incomprehensible that some modern businesses give it no room, no encouragement and no thought.

It is probable that the popular adoption of research methods has failed, due in part, to a psychological barrier built up around the word "research." Research, the word, possesses a certain strong dignity—it has been used to denote principally a high type of technical endeavor. Its popular use has surrounded it with an altogether faulty meaning whereby the impression has become but too firmly established that none but the highest types of technically trained experts can suitably carry on the work of research. We have come to understand that this lofty and remote type of activity was something for us to marvel at and consult deferentially, but we have perforce regarded it cooly as a brother, or fellow worker. Research means none of these super qualities, it only means "to look into again"—"to re-search." It is nothing if not based on simplicity—on the simple act of witnessing again and again the familiar and known things until knowledge of them becomes so full that a new and better step or method suggests itself. Progress in growth and research is but the intelligent directing of this growth in any or all of the influences which contribute to this natural process.

For our purposes here, then, let us discard the purely technical meaning of research and define it to mean all those activities of investigation into any and all phases of plant or manufacturing operations. We emphasize the word "all" for our meaning fundamentally includes the movements in every branch of the entire process. As a general proposition we do not think the statement will be disputed for an instant that any single production operation can in some way be bettered or made to yield more effective results. The old saying which relates that nothing is so good but that it may be improved, applies with equal truth to life in general and production operation No. 11 on part No. 13783 which calls for the drilling of a single one-quarter inch hole. The fact that even this minor step can be improved holds at once the incentive which makes effort possible and as well the hope

A paper presented before the Indianapolis Convention. The author, W. P. Woodside, manager methods and standardization departments, Studebaker Corporation, Detroit and South Bend, Indiana.

of advancement and progress. Were we compelled to admit that even in the most elementary operations no farther betterment could be hoped, we must admit the eventual stoppage and stagnation of all progress even to that of civilization itself which only measures its growth through the ever better and better utensils with which it maintains and carries on life. The research agency of which we speak is composed of many members. In a way each worker individually is a member of it. At any event it is a large group of workers or better still a vast potential force lying close to the heart of all operating activities and which has in its care and for its responsibility all of that businesses' hope of growth, advancement and success. It is no light load of responsibility that we are placing on research, in fact, it is pretty nearly the whole burden of future achievements which we are demanding and I believe we are not alone in thinking that no business can eventually prosper or even hold its own whose members, large and small, from the highest executive down to the humblest workman are not individually research workers in the sense we have endeavored to define the term. Particularly in this day of renewed competitive strife do we need men at the desk and at the drill press who will hold up their own work to the searching and re-searching of their own eyes, intent upon recognizing the little opportunities offered to each one to institute the new steps which mark progress in any line. Were it possible for us to stop at this point and get an expression from you as listeners as to your opinion of what has gone before I imagine we would hear somewhat such expressions as these:

"Surely, we agree, but how are we going to get such workers?"

"You've said nothing new—you're as regular as a party candidate."

"Utopian dreams are all right but—business is business, etc."

The development of individual constructive activity regardless of the individual's high or low position in producing operations is not novel. The theory which supports belief in personal initiative in even the most restricted of jobs is not new. The underlying and crying need of teaching and inculcating this principle, plant-wide, as it were, is a truth at once so vital and so elementary as to be apt to escape the sort of recognition which results in accomplishment. We are dealing with a principle, not a mere routine activity, when we concern ourselves with research in its total plant aspects. You cannot always apply a principle and make it bear immediate fruit in terms of measureable increments of achievement, but you can always teach a principle to those about you, be they friends, associates or fellow workmen. And if your teaching is persistent enough and intelligently enough directed, you can in time begin to realize results from its greater or less acceptance by your listeners. This is the fundamental fact of research endeavor—that it can be taught; that it can be inculcated as a mental principle and nourished into a positive healthy growth. Its method of attack is that of quiet, persistent infiltration, and with entire absence of violent gas activity. You can teach a man perhaps to protect his own safety by Safety-First campaigns, vivid posters and safety directions, stencilled thrice dimensionally on ceiling, walls and floor, but you can't make a man a good upright man by telling him to be so in print wherever his weary eye seeking rest and relaxation chances to pause. Neither can you form and cultivate that incomparable research faculty dormant, but still present in average individuals, by the blatant instrumentality of pictorial or printed appeal. As

the moral virtues in man are implanted far better by example than by precept so is that virtue of personal initiative best nurtured by similar means.

And this brings us down to the practical means by which we must realize the goal of widespread research effort throughout the plant. I have said enough I am sure, relative to the subject of teaching research as a principle to the whole plant to presuppose the existence of a teacher. Your research department as a department needs but one man, but he must be a teacher in every sense of the word. It is not by any means sufficient that he is able to talk or expound or orate—that would be to miss the point altogether. He must above all be endowed with that subtle faculty of educating which makes use of men's ambitions, which avoids awakening their reasonless resentments and gets across its message of real knowledge from the angle of common sense rather than of technicality. Such men are rare but they do exist and they are fundamental to our scheme. A man of this stamp needs helpers but he finds these helpers scattered here and there throughout the plant wherever personalities react favorably and right here is built up the main staff of research workers. And from this nucleus fingers sooner or later reach out farther and farther into all operations. Bear in mind if you will that we are now talking the practical ways and means. It is eminently practical and possible to find and select such a man as we have described And if it is practical and fundamental to find a high type of man to head any business enterprise it is equally practical and fundamental to seek a high type of man to organize research development.

It goes without saying that our research director must possess exact technical knowledge and that he must have at his disposal ample scientific equipment to carry out whatever technical work is required. He should have at his command the facilities of a laboratory equipped to do the kind of work which the particular business in which he is engaged, requires. There seem to be two ideals of laboratory work. Some laboratories seem to function wholly from within; that is, the laboratory staff recognizes a problem in the plant, retires to its sacred precincts, solves the problem, passes the solution on to the shop and is finished. In the meanwhile, countless other equally important problems suffer from lack of attention for the efficiency of this scheme depends entirely on the efficiency of the vision of the laboratory in recognizing a problem when it sees it—and laboratory eyes are always directed from without and not from within the job. To our mind the plant laboratory should be entirely and completely a checking institution. It should be a place of consultation; it should be the place to which problems are brought by those who personally are experiencing them and it should be the place where the theories and deductions of the plant are proved or disproved. In other words, the laboratory should be the servant, not the master. It should become the melting pot of the research staff—that and nothing more. It is only by this conception that we can hope to break down the barrier which most certainly exists today between workman and scientist, between job and technicality. And the putting of technicality into job and job into technicality can only mean, in the measure to which we succeed, the attainment of growth and progress from the basis of continual searching and researching.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A DISCUSSION OF PROF. H. F. MOORE'S PAPER ENTITLED, "THE FATIGUE OF METALS UNDER REPEATED STRESS"

By J. M. Lessells

THE remarks of Professor Moore to the effect that most of our design formulae can be likened to cartoons, would seem at first glance somewhat revolutionary, but the truth is apparent and engineers can profit by them. To state that the "endurance limit" seems to be more closely related to the ultimate stress rather than to the elastic limit may create wrong impressions in the minds of some and these statements should be approached with caution. Referring to Fig. 1, which shows the relative values of elastic limit and ultimate stress for a 3 per cent nickel steel, one in the annealed and the other in a heat-treated condition, it will be noted that the ratio of elastic limit, to ultimate stress for these steels is 0.3 and 0.75. Therefore if the working stress is based on the ultimate stress and is fixed at ½ of the ultimate stress, then the elastic limit in the annealed state would be exceeded, and permanent set would occur. It therefore seems misleading to base the endurance limit on the ultimate stress since working stresses cannot be so fixed.

With reference to the use of design formulae, Professor Moore has very

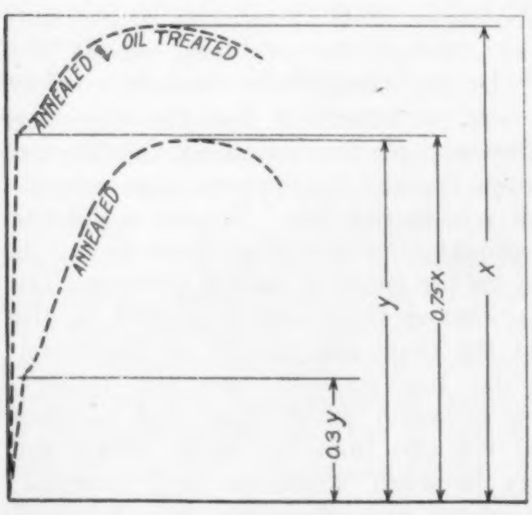


Fig. 1—Diagram of Apparent Elastic Limit and Ultimate Stress

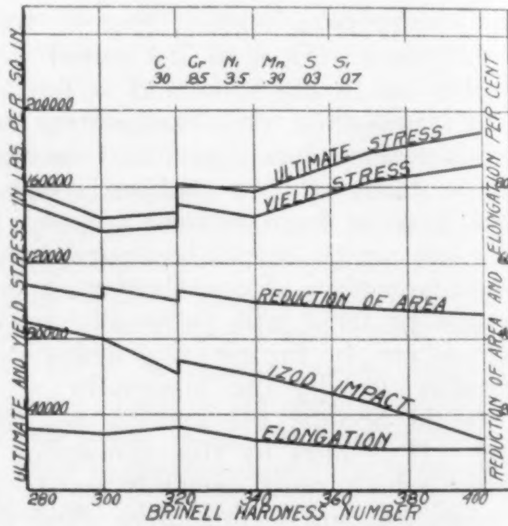


Fig. 2—Characteristics of Nickel Chrome Steel

aptly said that these should be applied with caution, but when an attempt is made to draw a comparison between Brinell number and endurance limit

A written discussion of Prof. Moore's paper presented before the Pittsburgh Chapter, and published in TRANSACTIONS of January 1922. The author, J. M. Lessells, is connected with the Westinghouse Electric and Mfg. Co., Pittsburgh.

the cartoon is becoming distorted, because the Brinell test was never intended for such a service. One of the reasons advanced for such apparent agreement between first, endurance limit and ultimate stress and second, between endurance limit and Brinell number is that too many steels have been compared on a common base, and after all, alloy steels have very little in common, with carbon steels. A suggestion put forward for future work is to compare all the varying characteristics of any one steel such as is shown in Fig. 2, which represents the characteristics of a nickel chrome steel, rather than endeavoring to correlate different steels. In this way the problem of comparing different steels will be simplified, but will always be more or less complex. Attention is drawn in Figure 2 to the similar manner in which reduction of area and Izod values respond to heat treatment variation. Both of these relate to crystal formation.

In Table I is shown the physical properties of three different steels each having the same Brinell hardness. If what has been suggested by Professor Moore, is true then steel *A* with 20 per cent reduction of area is as good in resisting fatigue as steel *C* with 50 per cent reduction of area, and all the past test data gathered around such tests may be relegated to the waste basket. This, in a word, with our present knowledge, is unthinkable, so let us move slowly. The idea advanced by Mr. W. J. Merten that the

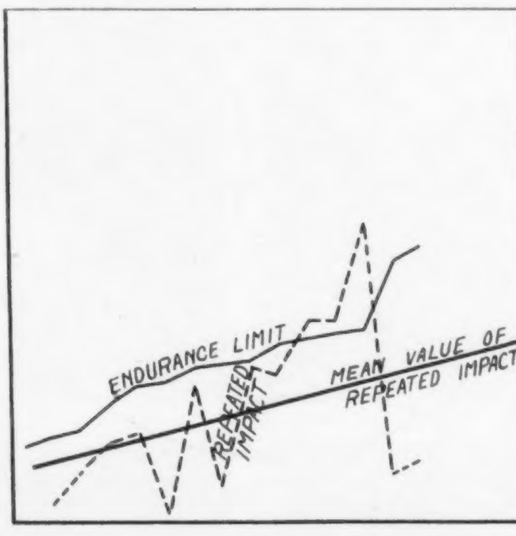


Fig. 3—Relation of True Elastic or Endurance Limit to Repeated Impact

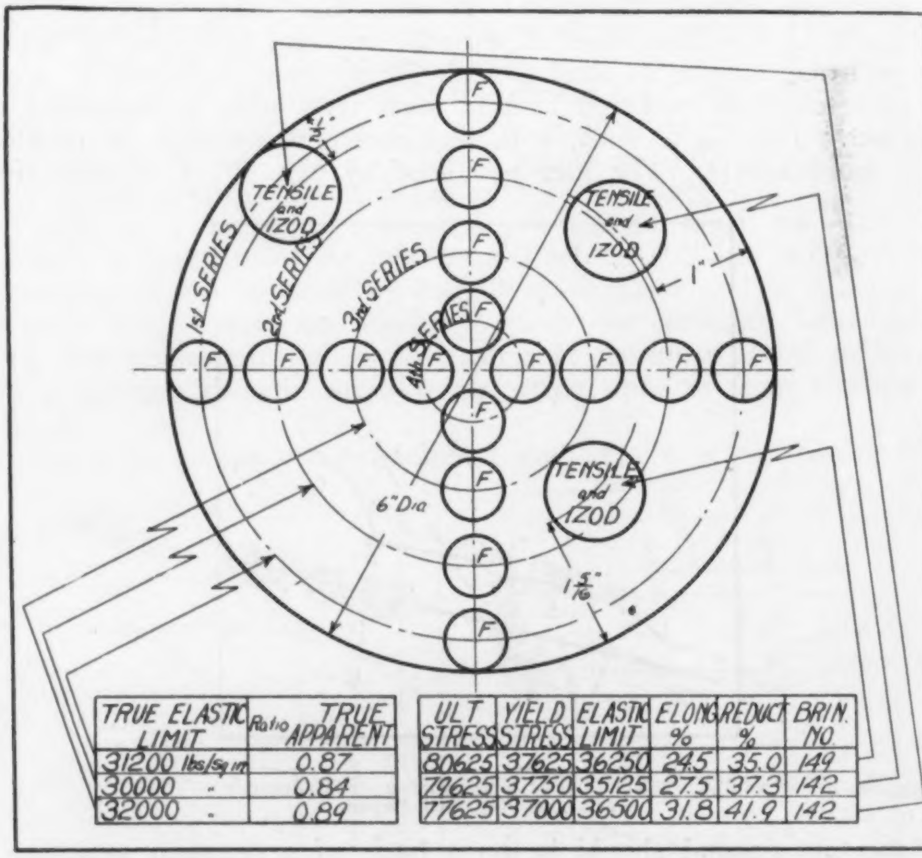
common meeting ground should be on a basis of a common structure, that is pearlitic, martensitic, or troostitic, after each steel has been explored, is a good one and worthy of further consideration.

As stated by Professor Moore, there seems to be no reason why impact tests should be related to endurance limit since each represent different conditions. The impact test is more or less localized by the notch while the endurance test is not so localized. This does not hold to the same extent with a repeated impact and there are reasons for believing that this test is some measure of fatigue. In Fig. 3 is shown plotted the values given by Professor Moore for endurance limit and repeated impact. It will be noted that a mean line has been drawn through these points apparently showing this relation, if allowance for possible notch error is considered. This is a very interesting phase of the subject. Our laboratory is proceeding

along such lines, because this is a very simple test to make, and it has been suggested recently that in the Stanton test, the number of blows required to fracture the test specimen is a measure of its resilience or the work required to cause the fracture. Summarizing these various points we have;

1. The results of Professor Moore indicate that endurance limit may possibly be related to ultimate stress. Since a comparison is made however, on many steels of entirely different characteristics this relation should be accepted with caution because there are evidently other factors involved.

2. The results further show that Brinell number is related to endurance limit but by "reductio ad adsurdum" this scarcely seems possible because the Izod test is related to reduction of area and the value of the Izod test results having been established, it seems wrong to discard these, a thing which must be done if Brinell number is to be a criterion of endurance.



TRUE ELASTIC LIMIT	Ratio TRUE APPARENT
31200 lbs/sq in	0.87
30000 "	0.84
32000 "	0.89

ULT STRESS	YIELD STRESS	ELASTIC LIMIT	ELONG %	REDUCT %	BRIN. NO
80625	37625	36250	24.5	35.0	149
79625	37750	35125	27.5	37.3	142
77625	37000	36500	31.8	41.9	142

Fig. 4—Shows location of test specimens and results obtained in the test of a 6-inch bar.

In Fig. 4 is shown the location of test specimens and part of the results obtained in the investigations which are being carried out in our laboratory on comparatively large sized material. The results shown were obtained in testing an annealed 0.44 per cent carbon steel. On the right hand side are shown the tensile properties taken from the region indicated, while on the left are shown the values of the endurance limit or true elastic limit as determined by tests similar to those described by Professor Moore. In this case each series of four fatigue test pieces gave the stress curve for determination of the endurance limit. This particular material was held at 850 degrees Cent. for 3 hours and cooled slowly in the furnace. The ratio of

true elastic limit or endurance limit to the apparent elastic limit is shown also. For properly annealed material there seems to be no difference between the outer and inner layers as far as fatigue endurance is concerned. We are

Table I

Characteristics of Three Different Steels

Material	Brinell No.	Ultimate Stress pounds per sq. inch	Elastic Limit pounds per sq. inch	Elong. per cent	Reduction Area per cent
A	414	190,000	104,000	8.6	20.2
		192,000	107,000	7.9	19.2
B	414	202,000	130,000	6.1	19.9
		198,000	127,000	6.3	22.4
C	414	191,400	168,000	14.2	53.3
		202,000	171,000	13.1	50.4

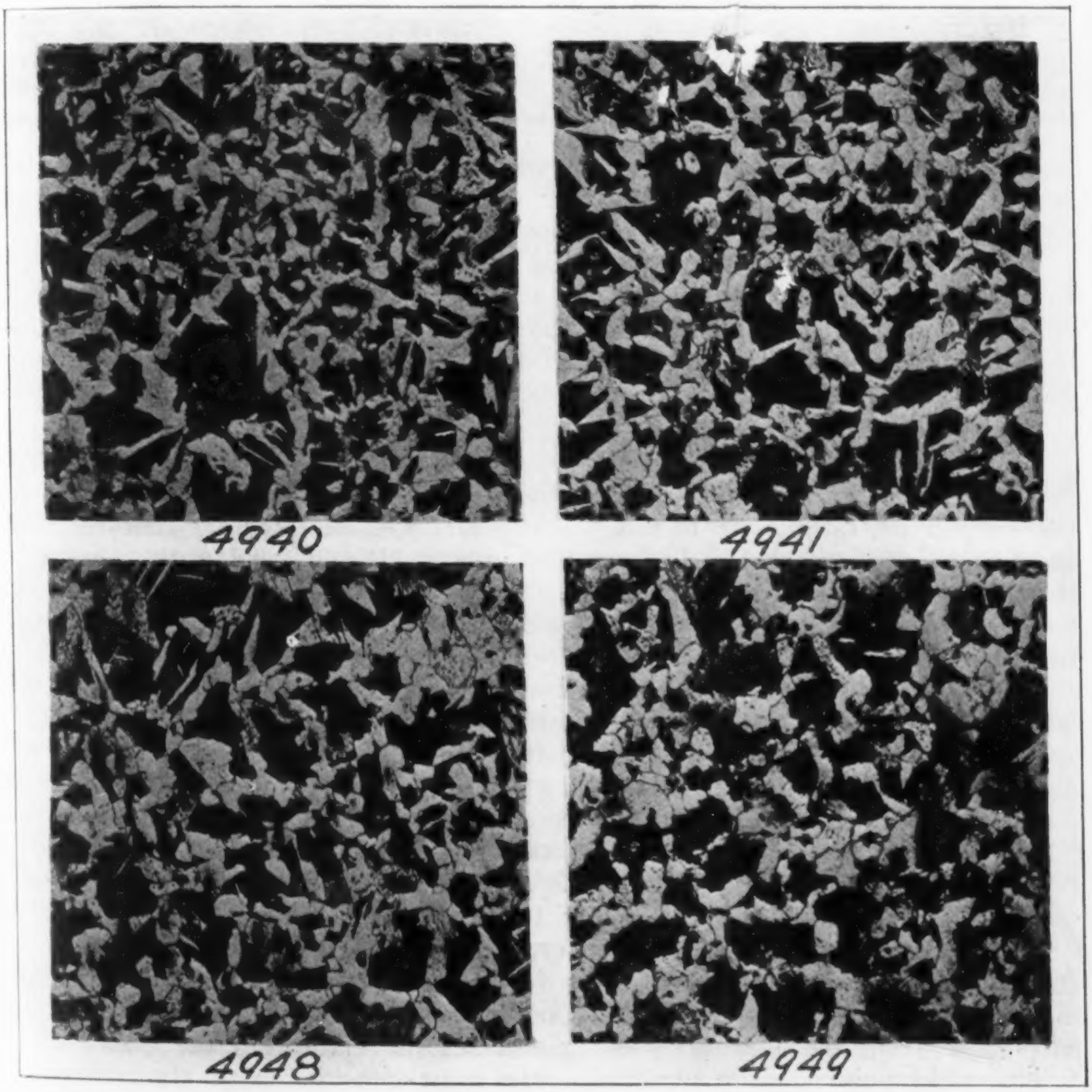


Fig. 5—Shows photomicrographs of four specimens tested.

still proceeding with these tests in our laboratory and it is still too early to draw any conclusions.

In Fig. 5 are shown a few photomicropraghs of this material indicating the characteristic pearlite structure of such steels. In Table II, is given the location of each, together with the stress conditions.

Micro photographs 4940 and 4948 were taken from the end of the test piece in the region of zero stress while the others were taken at the center in the region of maximum stress. No. 4941 is the structure obtained from the test which did not fail under 31,000 pounds per square inch stress in over

Table II

Stress Conditions and Locations of Photomicrographs Shown in Fig. 5

Photomicrograph No.	Series	Stress pounds per square inch	Number of Repetitions	Remarks
4940	1	zero	....	....
4941	1	31,000	8,671,000	Not broken
4948	3	zero	....	....
4949	3	33,000	1,772,000	Broken

eight and one-half million repetitions, while No. 4949 shows the structure upon which a stress of 33,000 pounds per square inch caused failure at slightly over a million and a quarter repetitions.

The writer wishes to express his thanks to the society in general and to Professor Moore in particular for making such a valuable contribution to this study of fatigue, and also for the liberty in being allowed to contribute this discussion in which the Westinghouse Electric & Mfg. Co. has allowed him to publish some of the results obtained in their laboratory.

AUTHOR'S CLOSURE

I have read with much interest the discussion by Mr. J. M. Lessells on the subject of fatigue of metals. With Mr. Lessells' feeling that tentative conclusions reached should be carefully examined, and used with caution by engineers I am in hearty agreement. I would like, however, to point out one or two points in his discussion with which I find it impossible to be in full agreement.

In the first paragraph of Mr. Lessells' discussion he speaks of fixing the working stress at one half the ultimate stress of the steel under test. I am sure nothing either in the written or the oral presentation of my paper would justify fixing the working stress at such a value. At Pittsburgh I did say orally that the endurance limit under reversed stress in flexure usually was about one-half the tensile strength, but I am very sure I never advocated using a working stress as high as the endurance limit, of course, any working stress should be far below the endurance limit if the material is subject to repeated stress. Moreover, it must be borne in mind that the determination of an endurance limit for reversed stress in no way releases the designer from considering the possibilities of static failure of machine parts, nor from considering working stresses in relation to the elastic limit or the yield point of the material. He must consider both static strength and fatigue strength. For some machine parts, for example, most "dead"

axles the elastic limit or yield point of the material is of prime importance, for others, for example, many "live" axles the endurance limit is of prime importance. For nearly all machine parts ductility is of importance as a safeguard against sudden shattering failure under the occasional heavy shocks of service. Later in his discussion Mr. Lessells speaks of discarding Izod test results and ductility tests if the endurance limit is accepted. Of course, nothing of the sort should be done. The fact that fatigue failure may occur does not in any way lessen the necessity of having material which has a high enough yield point so that it will not be permanently deformed in service, nor the necessity of having tough, ductile material which under occasional overload can withstand slight distortion without shattering failure. The user

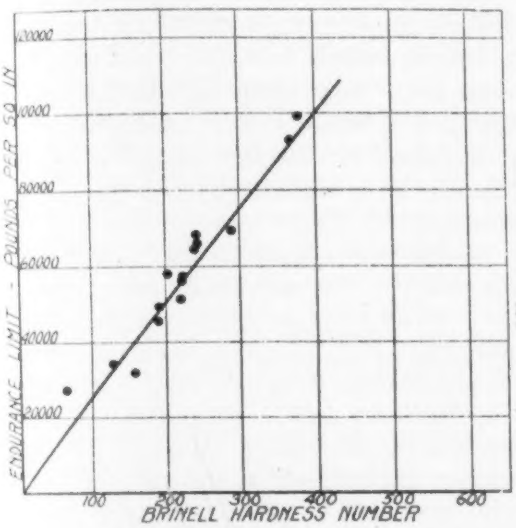


Fig. 1—Relation of Brinell Number to Endurance Limit

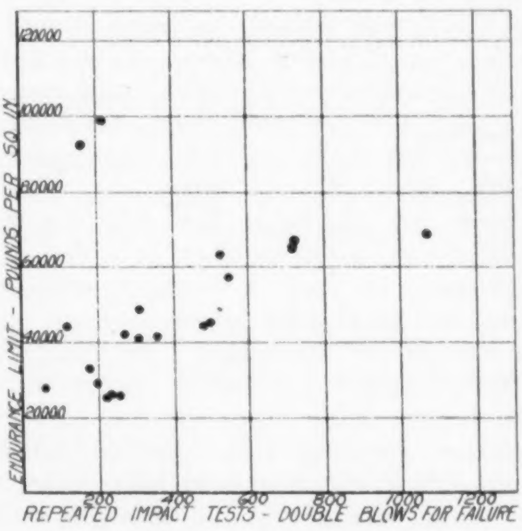


Fig. 2—Relation of Repeated Impact to Endurance Limit

of metal must never confine himself to one viewpoint, nor to one test for acceptibility of metal.

With reference to correlation between Brinell hardness and endurance limit under reversed stress the obvious answer to Mr. Lessells' "reductio ad absurdum" is to restate the fact that such correlation was found experimentally, as is shown by Fig. 1. Since the publication of the results of the investigation of the fatigue of metals at the University of Illinois, additional confirmation of this general correlation between Brinell hardness and fatigue resistance has been given first by Dr. McAdam of the U. S. Naval Engineering Experiment Station, second, in a letter from Mr. Gough of the British National Physical Laboratory, and third, in conversation by Dr. Gillett who is conducting fatigue tests at Cornell University. The results of the last-named tests indicate that this correlation becomes rather poor for Brinell hardness numbers above 400.

Moreover, it is not at all evident that such correlation is absurd. For some time it has been an observed fact that there was a fair degree of correlation between Brinell hardness and ultimate tensile strength. Microscopic examination of the process of fatigue failure shows it to be not a plastic deformation, but a progressive tearing a part or shearing apart of small particles of metal. It hardly seems unreasonable that such a progressive tearing or

shearing should be related to the tensile or the shearing strength of the metal, and to the related property of Brinell hardness.

In answer to Mr. Lessells' criticism of the attempt to find correlating physical properties for all grades of steel, and his proposal that such correlation should be sought only within narrow limits of variety of steel, the obvious answer is that with tests covering a fairly wide range of kinds of steel, including both carbon steel and alloy steel such correlation was actually found. This general conclusion has been checked by the results of Dr. McAdam's extensive tests, although he has interpreted endurance limit somewhat differently from the interpretation given at the University of Illinois.

Mr. Lessells' statement that "alloy steels have very little in common with carbon steels" seems altogether too sweeping, and it is difficult to see anything more than a bare assumption behind Mr. Lesselis' suggestion that in the future testing engineers should refrain from trying to correlate test results for different steels. How shall we decide which kind of steel to use for a machine part if we cannot correlate test results between different kinds?

In Mr. Lessells' Fig. 3 he has plotted a "mean line." He has not shown the scales used in that figure, and a reference to the original figure (Fig. 38, Bull. 124, Eng. Exp. Sta. Univ. of Ill.) shows that there is no scale for abscissas, but that the diagram merely shows values for steels placed one after another in order of the magnitude of endurance limit developed. In such a diagram, without scale values for abscissas any "mean line" has no significance whatever, and the "mean line" in Mr. Lessells' Fig. 3 should be discarded. In the accompanying Fig. 2, the lack of correlation between repeated impact tests and endurance limit is clearly shown, the results being from the test data given in Bulletin 124. This lack of correlation does not mean that we must "throw into the waste basket" the results of repeated impact tests, merely because such results do not seem to be a measure of fatigue strength under oft repeated working stresses. Such lack of correlation in no way lessens the force of the practical findings by a prominent British automobile firm, that the repeated impact test picks out good material to resist the occasional heavy shocks of automobile service.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. What is needle bar stock?

ANSWER. By R. H. Southworth, Betz-Pierce Company, Cleveland, Ohio. Needle bar stock is a bessemer screw stock having a very bright smooth surface due to cold drawing. It is drawn to exceedingly close accuracy as to size. It machines freely in automatic screw machines and is particularly adapted for application to various automatic devices and appliances. A high surface finish lends itself well to nickel plating where parts are to be so treated. A few important applications of this material are: Its use in adding machines, addressing machines, billing machines, computing machines, moving picture machines, phonographs, sewing machines, typewriters, vacuum cleaners, etc.

QUESTION NO. 6. Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?

ANSWER. By T. G. Selleck, of Chicago, Illinois. Many tests have been made to determine the variations of temperature between the interior of carbonizing boxes and that of the furnace chamber and the results have been carefully charted.

While a large majority of these tests prove that the box temperature, on an average, is much below that of the furnace, the two charts shown here indicate that it is not impossible to have a reversal of those conditions. In making these particular tests, boxes were especially fitted with protecting tubes for the thermocouples reaching to the inside center of the box while another thermocouple was suspended directly over the box in the heating chamber of the furnace and within ½-inch of the cover of the box, the distance between the hot junctions of these couples being about four inches.

In the charts shown the solid line indicates the temperature of the furnace and the dotted or broken line that of the interior of the box. One of the most pronounced cases of excess temperature inside the box is shown in Fig. 1. In this test it is shown that the temperature within the box may at times be very much higher than the furnace temperature. The operator may be wholly unaware of this condition, and with no way of knowing anything about it until the operation is completed and the ruined work tells the story. In this instance it will be observed that the temperature of the interior of the box exceeded the furnace temperature over 200 degrees Fahr. 3½ hours after charging. After the fire had been turned off and the furnace temperature reduced, the interior temperature continued to rise while the furnace temperature fell very rapidly. The two temperatures could not be brought into equilibrium, as the chart in Fig. 1 shows.

Oftentimes operators find conditions in their carbonized work, such as excessive brittleness, peeling or spalling of the case, for which they appar-

ently can find no cause. Such physical conditions in the treated pieces arise sometimes, in fact more often than not, from operating conditions such as are represented in this chart, and of which the operator has no knowledge whatever unless he makes a very close examination of the carbonizing equipment. In looking for the cause of these conditions in the test, it was discovered that the box was defective. There was a small hole in the box, and the hole was not observable when the box casting was new because of scale that covered it. Finally this hole developed into a very convenient entrance for oxygen, which combined with the carbonizer and produced a lively combustion within the box. Without the presence of the pyrometer thermocouple in this box, the operator would have no means of knowing why his results did not conform with previous records. Without the thermocouple there would not have been a reduction of the furnace temperature,

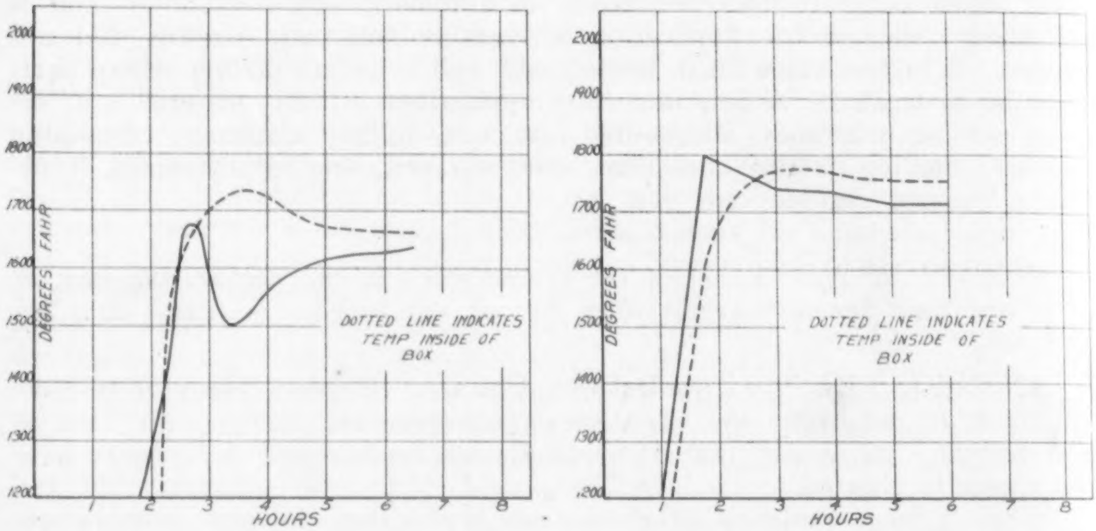


Fig. 1—A pronounced case of excessive temperature inside of carbonizing box.

Fig. 2—Excessive temperature within carbonizing box due to an imperfect carburizer.

and there is no telling to what temperature the interior of the box would have gone, but it is certain that it would have been so high that over-carbonization would have resulted.

Fig. 2 is the record of another test in which the box temperature was above the furnace temperature for several hours. In this instance, however, we find a different cause, the use of an imperfect carbonizer. By imperfect is meant a carbonizer that upon its first use is so fully of highly combustible matter, that it almost flares up when subjected to a temperature above the ignition point of a heavy oil. Under such conditions the internal combustion is started at the very beginning of the operation and increases as the temperature of the furnace rises. In this instance the pyrometer told the story and the operator was able to save the material.

QUESTION NO. 8. *What is the effect of high and low silicon in tool steel?*

QUESTION No. 9 *In carbonizing does not the carbon increase slightly even in the core section?*

ANSWER. By T. G. Selleck of Chicago, Illinois. The writer went into this question very thoroughly some years ago and after careful investi-

gation satisfied himself that if the carbon content of the core of carbonized steel shows an increase, it was due to one of two things. First, faulty heat treatment after carbonization, or second, an excessive temperature during the carbonizing period. If a test bar of known carbon content is carbonized and is allowed to cool down in the carbonizer, and is afterward fractured before any heat treatment is applied to it, the fracture will show the exact physical condition of the metal during the carbonizing period. The structure is very open and irregular and there is no well defined line between the case and the core. If the center of the core is analyzed at this time, it will probably show a slight increase in carbon content. If the bar is then quenched at the critical temperature of the original metal and again analyzed, the core should show its original carbon content. This is true only where the carbonizing temperature is not more than 200 degrees Fahr. above the critical temperature of the steel. If an excessive temperature is used there will be a permanent increase of the carbon content. The fracture of the untreated carbonized bar shows how very easy it is for gases to permeate the highly expanded metal, and in the slow cooling, some of the carbon may become deposited far beyond the mass of the element introduced.

In the quenching at the proper temperature, the carbon is segregated at the surface of the metal and the vagrant atoms of that element lying deeper down seem to fly out to join the mass. Many tests have shown that even on very thin sections there will be no increase of carbon content in the core if proper heat treatment is applied, but the single quench method will undoubtedly leave the excess carbon wherever it may locate itself, because the single quench temperature is usually too low to correct the core. If careful double heat treatment is given carbonized parts, the core should maintain its original carbon analysis.

QUESTION NO. 10. ***What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?***

QUESTION NO. 11. *Has high speed steel ever been carbonized and if so what were the results?*

ANSWER. By S. C. Spalding, Metallurgist, Halcomb Steel Co., Syracuse, N. Y. The carburizing of high speed steel in the same sense that machinery or low carbon case hardening grades of steel are carburized; that is, the production of a hard case or shell on a soft core, has never, so far as I can learn, been attempted commercially. Carburizing action on high speed steel is resorted to at times in cases where improper heating has caused the burning out or removal of some or all of the carbon in the portions of the steel at or near the surface. When the steel in this condition is quenched from the hardening heat the portions where the carbon has been lowered or removed will not harden and if the tool is such that this soft surface cannot be removed by grinding, the tool will be useless. In cases where the making up of a new tool would be very costly, it will usually be worth while to try and salvage the decarburized tool by a carburizing process. Sometimes this is done by packing the tool in compound or charcoal and heating it to a hardening heat of 2200 to 2300 degrees Fahr., holding it for a short time at heat, then quenching from the pot. This method while sometimes successful, is very risky as it is impossible to see what is going on in the pot and very often due to the high temperature attained and the absorption

of too much carbon the cutting edges will be melted away and the tool hopelessly spoiled.

A longer but much safer method of treatment is to pack the tool in a mixture of old and new compound and heat it to 1650 degrees Fahr., hold for two to three hours, depending on the depth of decarburized zone, then let the tool cool off in the pot, which has been removed from the furnace. When cold, remove the tool clean it off thoroughly, then harden it in the regular way, keeping the temperature 2250 to 2300 degrees Fahr., and watching very carefully for signs of blisters. If the hardener doing this work is experienced enough to judge the proper mixture of compound and time to run it at carburizing heat, an otherwise spoiled tool can be redeemed. The great danger lies in getting the concentration of carbon on the outside too high, which lowers the melting point and causes any fine edges on the tool to blister and melt at the hardening heat, or even if not melted, to be brittle and tend to crumble in use.

Summing up, we might say that by a carburizing process an otherwise spoiled tool can be redeemed and made to do some work, but that the job is a risky one, requiring considerable care and experience and we might almost add, good luck.

QUESTION NO. 12. *How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?*

QUESTION NO. 13. *A swaging die for tubing receives* 3600 *blows per minute. It has been found that a scleroscope hardness of about* 95 *is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?*

QUESTION NO. 14. *What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.*

QUESTION NO. 23. *Why is it that a piece of hot rolled steel, of a given composition, will not harden in oil after carbonizing to the degree that a piece of the same composition will if first subjected to forging?*

QUESTION NO. 24. *Do steels of similar composition respond similarly to case hardening operations, and providing these are properly conducted, will satisfactory results always be obtained?*

QUESTION NO. 25. *What is the difference between magnification and enlargement in taking photomicrographs?*

QUESTION NO. 26. *Does the presence of pearlite in the decarburized zone of a malleable iron casting effect the resistance of this casting to shocks?*

QUESTION NO. 27. *What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?*

QUESTION NO. 28. *What is the role of manganese in steel?*

QUESTION NO. 29. *Does the macrostructure of a piece of steel ever reveal imperfections which cannot be observed under the microscope or through chemical analysis?*

QUESTION No. 30. *How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?*

QUESTION No. 31. *What is the effect of oxidizing gases at low pressure on heated iron?*

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

MORE ABOUT CHEMICAL ENERGIZERS. By H. B. Knowlton. *Forging and Heat Treating*, Vol. 8, Page 141.

Exception is taken by Knowlton to statements made in an article by C. E. Carpenter entitled "Specifications Which Don't Specify." Experiments were conducted to show (a) that energizers do have an influence on charcoal which they are not actually in contact with, (b) that the energizer in impregnated pellets will be practically as efficient as those on coated pellets and (c) that good energizers are not necessarily insoluble in water. The need of uniformity in commercial carbonizing compounds is pointed out.

FERROUS AND NONFERROUS MATERIALS

IRON AND STEEL CLASSIFIED FOR DESIGNERS. By W. J. Merten. *Blast Furnace and Steel Plant*, Vol. 10, Page 230.

The characteristics, uses, physical properties, and heat treatment of wrought iron, malleable iron, grey iron, and semi-steel are covered primarily for the benefit of the designing engineer. Photomicrographs illustrating the effect of heat treatment are included.

NEW ALUMINUM ALLOYS OF HIGH STRENGTH. Anon. *Chemical and Metallurgical Engineering*, Vol. 26, Page 689.

The material presented is taken from the Eleventh Alloys Research Report of the Institute of Mechanical Engineers. Tests at temperatures up to 350 degrees Cent. show that an aluminum alloy containing copper, nickel, and magnesium has the best possibilities for pistons. Data is also given on alloys suited for rolling, forging and extruding. As a result of investigations on the influence of heat treatment it is stated that the compound Mg_2Si is responsible for most of the hardening produced on aging quenched aluminum alloys.

METALLOGRAPHY AND CRYSTAL STRUCTURE

THE EFFECT OF IMPURITIES ON RECRYSTALLIZATION AND GRAIN GROWTH. By C. J. Smithells. Presented at the March Meeting of the British Institute of Metals.

To account for the results obtained in an investigation on the influence of soluble and insoluble impurities on the recrystallization of tungsten, the author postulates that the vapor pressure of the individual crystals is the controlling force. On this basis recrystallization takes place by a process of distillation, the atoms going from a crystal of higher vapor pressure to one of lower vapor pressure. The effect of grain size, heat gradients, and strain gradients are interpreted on this basis.

DETERMINING COEFFICIENT OF EXPANSION WITH A METALLURGICAL MICROSCOPE. By H. C. Knerr. *Chemical and Metallurgical Engineering*, Vol. 26, Page 644.

A method for determining the coefficient of expansion of a substance, using only equipment available in nearly any metallurgical laboratory is described. Substances of known coefficients of expansion are placed on each side of the specimen and pined at one end. Hair lines are ruled across the three pieces at each end while the pieces are at a known temperature. Changes in the positions of these hair lines are then noted by means of an inverted microscope, the specimens resting on the glass bottom of a thermostat.

THE STRUCTURE OF WHITE-HEART MALLEABLE. By Rudolf Stotz. *Foundry*, Vol. 50, Page 286.

White-heart malleable consists of an outer layer of ferrite which may contain some pearlite and an inner core composed of graphite, ferrite, pearlite, and some-

times cementite. The tensile strength is about 5200 pounds and the elongation 4 per cent. Numerous photomicrographs illustrate the influence of varying amounts of carbon, sulphur, and of over-oxidizing are shown.

THEORY OF THE HEAT TREATMENT OF STEEL—III. By W. M. Mitchell. *Forging and Heat Treating,* Vol. 8, Page 162.

The effect of quenching in various media (brine, water, oil, and the air blast) is discussed and the proper temperatures for varying amounts of drawing are given. In considering the heat treatment as a whole the previous treatment of the metal must be given consideration.

TENACITY AND TENSILE STRENGTH. By F. Korber. *Stahl und Eisen,* Vol. 42, Page 365.

In case of plastic deformation the increase in strain is proportional to the decrease in cross section. A formulae is given by which the tensile strength may be calculated from the constants of the line equation for the change in deformation with change in tension. The influence of the form of crystal structure on the degree of deformation is studied by means of x-ray spectrographs.

PROBLEMS OF DESIGN AND FABRICATION

PERFECTING A DROP FORGING. By J. H. G. Williams. *Forging and Heat Treating,* Vol. 8, Page 152.

The forged portion of a mechanic's square is taken as an example. Instances of how "cold shuts", "laps", and "mismatches" may occur are illustrated with photographs and the remedies discussed.

HARDNESS TESTING ON A COMMERCIAL SCALE. By E. F. Lake. *Iron Age,* Vol. 109, Page 913.

The difficulties encountered in the commercial inspection of automobile pistons and connecting rods are enumerated and the conclusion is drawn that some method of testing other than Brinell hardness might prove more satisfactory on these articles.

WEAR ON VARIOUS AUTOMOBILE GEAR STEELS. By E. R. Ross. *American Machinist,* Vol. 56, Page 72.

The object of the investigation was to determine the best material for automotive transmission gearing, resistance to wear being used as a basis. The tests reported were on S. A. E. 2345 steel. Slight differences in carbon content notably influenced the wear. Wear on the gear cutters was also found to promote deterioration of the gears.

LEAD HARDENING FURNACES FOR HEATING HAMMERS AND HATCHETS. By G. T. Straub. *Forging and Heat Treating,* Vol. 8, Page 160.

A lead pot installation for hardening hatchets and hammer heads is described. The outfit is equipped with a preheating chamber to utilize waste heat and this also serves as a means of producing charcoal for the lead pots from waste hickory handle blanks.

THE DEPENDABILITY of CAST IRON WELDING. By G. O. Carter. Paper presented before the Cleveland Section of the American Welding Society.

Welded grey iron castings may be depended upon provided the broken parts are properly preheated previous to the welding operation and subsequently allowed to cool slowly. Examples of welded cylinder blocks, die press frames, etc., are discussed and illustrated.

TOOL STEEL

SELECTION AND HEAT TREATMENT OF TOOL STEEL. By S. C. Spaulding. *Blast Furnace and Steel Plant,* Vol. 10, Page 224.

The points to consider in selecting a tool steel are (1) ease of fabrication, (2) permissible dimentional changes on hardening, (3) ease of hardening, (4) nature of service to which tool will be put (heavy or light cuts), (5) nature of material to be cut by tool, (6) temperature of material to be cut, and (7) amount of production expected from the tool. Proper methods of heating, quenching, and tempering tool steels are discussed in a very general way.

ELECTRIC TOOL STEEL MELTING PRACTICE. By W. J. and S. S. Green. *Iron Age,* Vol. 109, Page 999.

In tool steel melting where refining plays no part in the operation, basic bottoms are recommended. Cold charges are to be preferred to molten metal. Double voltages of 115 to 125 high and 75 to 85 low have been found to give satisfactory results.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

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WORCESTER POLYTECHNIC INST., (M-3), Att. F. W. Roys.
YOUNGBERG, Robt., (M-4), 445 Second St., Elmhurst, Ill.
ZIMMERMAN, H. B., (M-6), McCormick Wks., International Harvester Co., Chicago, Ill.

CHANGES OF ADDRESS

ANDERSON, G. R., (M-4)—from 1041 Goodlet Ave. to 1148 Groff, Indianapolis, Ind.
ARTHUR, J. E., (M-12)—from 36 Rhodes Ave., S. Charleston, W. Va. to Box 667, Midland, Pa.

BARNES, CHAS., (M-3)—from 2009 S. 23rd St. to 1933 McKean St., Philadelphia, Pa.
BARR, Wm. JR.—from Hughes Tool Co., Houston, Texas to Hughes Tool Co., Los Angeles, Cal.
BONNING, F. W., (M-1)—from the Cummings Co., Boston, Mass. to 28 Broadway, Malden, Mass.
BROWN, F. D., (M-2)—from 6014 Belvidere Ave., Cleveland to Antrim, N. H.
BRUA, G. E., (M-10)—from Rock Island, Ill. to 353 E. Orange St., Lancaster, Pa.

COX, A. M.—from R. D. Nuttal Co. to Pittsburgh Commercial Treating Co., 7143 Frankstown, Pittsburgh, Pa.

DAMICO, A., (M-5)—from 1744 E. Passyunk Ave. to 729 Pierce St., Philadelphia, Pa.
DARFLER, R. W., (M-3)—from 209 Lewis St., to 337 Collins St., Blue Island, Ill.
DAVIS, F. G., (A-10)—from 1437 Franklin St., E., to 2444 Grand Blvd., Detroit.
DAVIS, T. L., (M-2)—from Woodward Governor Co., Rockford, Ill.
DIETZMAN, H. M., (M-3)—from 615 Collings Ave., W. Collingswood, N. J. to 34 Congress Rd., Lakewood, N. J.

FELKER, A. W., (A-2)—from 1598 Elbur Ave., Lakewood, Ohio, to Crucible Steel Co. of America, 1723 Lafayette Blvd., Dettroit, Mich.
FITZGERALD, M. V., (M-2)—from 691 State St., to 89 Linden St., Springfield, Mass.
FLANNERY, W. R., (A-4)—from 2849 Equitable Bldg., New York City to 849 Book Bldg., Detroit, Mich.

GEISSINGER, H. C., (A-4)—from 411 Kresge Bldg. to 6337 Charlevoix Ave., Dettroit.
GRAHAM, W. F.—from Truell Court, Plainfield, N. Y. to Y. M. C. A., Hartford, Conn.

HANDY, H. E., (M-3)—from 173 Elmwood Ave., Providence, R. I. to Saco-Lowell Shops, Lowell, Mass.
HERB, J. W., (M-2)—from 416 Ferry St., to 729 Washington St., Easton, Pa.
HODGE, J. E., (M-5)—from 1921 Irving Ave. S. to 1760 Hennepin Ave., Minneapolis.

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JENKS, W. E., (M-3)—from 2166 DeForest Rd. to 11417 Continental Ave., Cleveland.

KELLY, J. N., (M-4)—from 275 Caroline St., Derby, Conn. to Care Higley Machine Co., S. Norwalk, Conn.
KERR, CHAS. A. T., (M-12)—from 21 W. 16th St. to 2107 N. Penn, Indianapolis.
KOEHLER, CHAS., (M-9)—from 78 Grove St., to 72 Freeman St., Hartford, Conn.

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LICKTEIG, A. F., (M-4)—from A. C. Gilbert Co. to 14 Fox St., New Haven, Conn.
LIZOU, LEO, (M-12)—from 1372 Richard St. to 767 55th St., Milwaukee, Wis.
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LOWRY, J. E.—from Coliver Chilled Plow Wks., to Box 248, South Bend, Ind.

MANN, R. L., (M-5)—from Tate-Jones & Co. to 37 Allen St., Buffalo, N. Y.
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MILLER, S. W., (M-10)—from 349 Orchard St., Rochester, N. Y. to Union Carbide & Carbon Research Lab., Long Island City, N. Y.
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McCONNELL, J., (A-2)—from 2605 E. 7rd St., Chicago, to United Alloy Corp., Canton, Ohio.

PAFENBACH, C. R., (M-6)—from 66 Walnut St. to 11 Lakeview Pkwy., Lockport, N. Y.
PRICE, J. M., (A-4)—from Electro Sales Corp. to 30 E. 42nd St., New York City.

REDDERSON, E. W., (M-4)—from 935 W. 68th St. to 6909 S. Green St., Chicago.
RODNEY, K. R., (M-4)—from New Castle, Del. to Highland Iron & Steel Co., Terre Haute, Ind.

SADTLER, C. B., (M-1)—from 61 Roslyn Ave., Glenside, Pa. to 1615 N. Meade Ave., Chicago, Ill.
SCHAGRIN, H., (M-12)—from 6 White Ave., S. Charleston, to Care Blumenfeld, 1115 S. Frankfort, Tulsa, Okla.
SHERMAN, P. B. JR., (M-1)—from 2108 E. 96th St., Cleveland to Room 608 Y. M. C. A., Canton, Ohio.
SKOOG, C. F., (M-12) from 711 E. Harvey St. to 2510 Erskine Blvd., South Bend.
SMART, C. F., (M-3)—from 1617 Holden Ave., Detroit to Oakland Motor Car Co., Pontiac, Mich.
STEVENSON, C. M., (A-12)—from Colonial Steel Co., Toledo, Ohio to P. O. Box 645, Pittsburgh, Pa.

TAYLOR, JAMES, (M-1)—from 312 3rd St., Scotia, N. Y. to 120 Degraff St., Schenectady, N. Y.

WEED, H. C., (A-4)—from 4654 N. Monticello Ave. to 4737 Lawndale Ave., Chicago.
WHITEHEAD, SGT. W. F., (M-3)—from Camp Pike, Ark. to Q. M. C., Manila, P. I.
WILLIAMS, R. L.—from Crucible Steel Co. ot Lenox Hotel, Detroit, Mich.
WOODWARD, A. F., (M-4)—from 432 Hawkins St., Cincinnati to 1483 E. 65th St., Cleveland, Ohio.

MAIL RETURNED

ASKEW, HARRY J., Jr., Crucible Steel Co. of America, Detroit, Mich.

FULLER, E. C., 341 Endicott Bldg., St. Paul, Minn.

GAUGHAM, E. J., 2722 N. 28th St., Philadelphia, Pa.

HALTER, J. L., (M-12), 8 White Ave., S. Charleston, W. Va.

PYNE, J. E., (M-4), Diamond Alloy Tool Co., St. Louis, Mo.
ROSE, HANS, Noroton Heights, Conn.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Friday, Franklin Union, Corner Berkley and Appleton Sts., Meeting 8:00 P. M.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Thursday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Merchants Association of New York, Woolworth Building.

Philadelphia—Last Friday, Engineers Club.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Rochester—Second Wednesday.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri City—First Thursday following first Monday.

Washington—Second Friday.

STANDING OF THE CHAPTERS

In the May issue of the TRANSACTIONS was published the standing of the chapters as of April 1st. The list below shows the standing of the chapters on May 1st.

1. Chicago
2. Detroit
3. PITTSBURGH
4. *Philadelphia*
5. Cleveland
6. New York
7. HARTFORD
8. *Indianapolis*
9. BOSTON
10. LEHIGH VALLEY
11. †*Syracuse*
12. †Milwaukee
13. WORCESTER
14. CINCINNATI
15. **North West*
16. **Rockford*
17. Tri City
18. SPRINGFIELD
19. PROVIDENCE
20. *St. Louis*
21. Schenectady
22. New Haven
23. *Washington
24. *Buffalo
25. Toronto
26. South Bend
27. Rochester
28. Bridgeport
29. Gary

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The following explanations will be of assistance. The chapters shown in capitals have advanced their position from that occupied on April 1st. Those shown in italics are not occupying as high a position as in the previous report.

Pittsburgh continued its stride during the month and passed another chapter. At the present time it occupies position No. 3 and has served notice that within a short time it expects to occupy position No. 2.

The tie last month between Hartford and Indianapolis resulted in favor of Hartford and that chapter is occupying No. 7.

All members of the Society should give the above report very care-

ful consideration and should lend every effort to advance the positions of their chapters.

Many of the chapters are separated but by a few members and an increase of only a small number would serve to make a radical rearrangement of the whole list.

BRIDGEPORT CHAPTER

The Bridgeport Chapter held its April meeting on Friday, the 21st in the Camber of Commerce rooms. This was the annual meeting of the year in which the report of the secretary and treasurer was made and the election of officers for the coming year. H. T. Dow was elected chairman; E. M. Hays, vice chairman; and C. F. Schmelz, secretary-treasurer. E. B. Crocker, H. M. Ellsworth and L. F. Schwerdtle were elected members of the executive committee.

The program for this meeting consisted of four reels of moving pictures taken at the plant of the American Sheet & Tin Plate Company entitled "Manufacture of Steel for Sheets & Plates," which covered all of the operations from the ore to the shipping of the finished plate. Following these pictures a comedy reel was exhibited.

About 75 members and guests attended this meeting.

PITTSBURGH CHAPTER

The annual meeting of the Pittsburgh chapter was held May 1st at which time Dr. Unger gave a very interesting and instructive talk entitled "The Need for More Practical Information in Industry." This paper was very well received and proved to be of vital interest to steel treaters. The annual report and election of officers was held at this meeting. The officers for the ensuing year are as follows:

N. B. Hoffman, Colonial Steel Company—Chairman; W. J. Merten, Westinghouse Electric & Mfg. Company—vice-chairman; D. W. McDowell, secretary-treasurer. The following members of the executive committee were elected; C. M. Johnston, Crucible Steel Company of America; Geo. Loefler, Carbon Steel Company; A. M. Cox, Pittsburgh Steel Treating Company; Frank Garrett, Latrobe Steel Company; S. L. Goodale, University of Pittsburgh; W. H. Phillips, R. D. Nuttall Company; Prof. F. M. Crabtree, Carnegie Institute of Technology; D. H. Horne, United Chemical Company; B. D. Sachawalla, American Vanadium Corporation; W. Buechner, E. F. Houghton; W. B. Crowe, Carnegie Steel Company.

SOUTH BEND

The South Bend chapter held its annual meeting May 9th at Kables Banquet Hall. The meeting was preceded by a dinner attended by 33. At this meeting the following officers were elected unanimously: J. A. Kingsbury, chairman; W. F. Newhouse, 1st vice-chairman; C. B. Peterson, 2nd vice-chairman; S. Shagaloff, secretary-treasurer.

Mr. W. J. Harris was elected chairman of the membership committee.

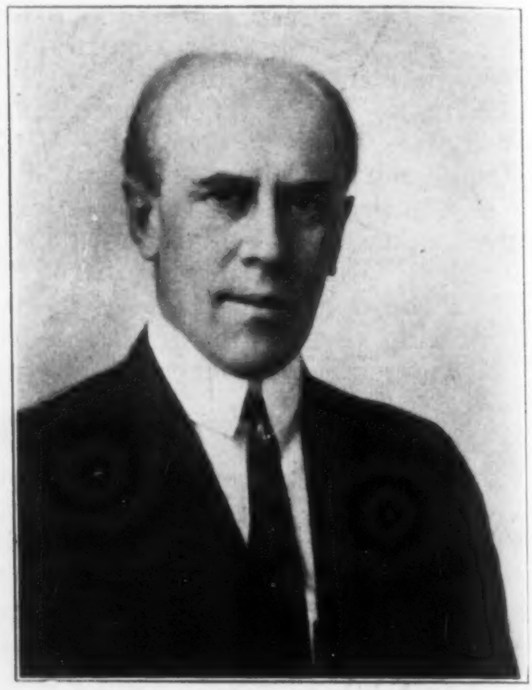
Following the election Mr. C. L. Richie read a paper on "The Recent Advances made in Heat Treatments," and Mr. A. E. Tarr of the Leeds & Northrup Company gave a talk on "Electric Furnaces".

Regular meetings of the chapter were adjourned until September 12th, due to warm weather.

WASHINGTON CHAPTER

At the April meeting of the Washington Chapter, held on the 21st in the auditorium of the Interior Department Building, National President, Frank P. Gilligan, presented a paper on "The Influence of Quality from the Standpoint of Workmanship and Material." An unusually clear explanation of the iron-carbon diagram and its application in the heat

H. J. French, re-elected chairman, Washington Chapter.



Alexis Caswell, re-elected secretary-treasurer of North West Chapter.

treatment of various carbon steels was first presented after which a large number of failures in service were shown and the methods of determining their causes explained in considerable detail.

Among the interesting items was a comparison of methods used by what might be called the "two schools in heat treatment," namely, that favoring high temperatures for short times vs. that advocating the use of lower temperatures for relatively long periods in normalizing and breaking up refractory structures. The value of the fracture test and macroscopic etching for inspection of steel and in determining causes of failure was also clearly shown.

Mr. Gilligan's paper was unanimously declared to be of exceptional merit and interest and following its presentation a short but lively discussion was undertaken by the members present.

On Monday, May 22, the Washington Chapter held its regular meeting at which Professor Haakon Styri, Director of Research of the S. K. F. Laboratories, Philadelphia presented a very interesting paper entitled "Preparation and Heat Treatment of Ball Bearing Steels". In

this paper he discussed the preparation of high grade alloy steels for manufacturing ball bearings and bearing parts. He laid considerable stress on the point that great skill and experience is required in handling these steels. Heat treating and hardening steels for automotive bearing purposes were thoroughly discussed by Prof. Styri.

The laboratory with which Prof. Styri is connected has devoted a great deal of attention and study to the proper quenching temperatures and the proper rate of cooling of these steels.

The speaker's experience in this work combined with illustrations of the results he has obtained were exceedingly interesting.

A lively discussion followed this paper which was of benefit to all.

NEW YORK CHAPTER

The May meeting of the New York Chapter was held in the Assembly room of the Merchants Association in the Woolworth Building, Wednesday, May 17.

The program for this meeting was a paper presented by C. M. Blackman, Foreman of the hardening departmnt of the Colt's Patent Fire Arms Mfg. Company, Hartford, entitled "The Heat Treatment of High Speed Steel".

Mr. Blackman is a man who has had many years practical experience in the heat treatment of steel and discussed his subject from a practical stand-point rather than the technical. He brought out many points of interest to tool hardeners as evidenced by the interesting discussion which followed his paper.

The election of officers for the ensuing year took place at this meeting. They will be announced later.

ROCKFORD CHAPTER

The Rockford Chapter held its regular May meeting Wednesday the 10th. Mr. James P. Gill, Metallurgist, Vanadium Alloys Steel Company, Latrobe, Pa., presented a very interesting paper entitled, "High Speed Steel". He discussed very thoroughly its manufacture, heat treatment and its metallography. Mr. Gill has devoted a number of years to the research of high speed steel and handled his subject in a very comprehensive manner. A very interesting discussion followed Mr. Gill's paper and much valuable information was obtained by those present.

Election of officers for the ensuing year was held after Mr. Gill's paper.

CHICAGO CHAPTER

Chicago Chapter held a meeting, Thursday evening, May 11 at which time, Mr. James P. Gill, Metallurgist, Vanadium Alloys Steel Company, Latrobe, Pa., presented his very capable paper entitled "High Speed Steel." In presenting this paper Mr. Gill included information as to the manufacture, working, heat treatment and metallography of high speed steel. Mr. Gill has done a great deal of research work on high speed steels and was able to present some very interesting data on the recent developments of this metal. An interesting and instructive discussion followed this paper.

PHILADELPHIA CHAPTER

The April meeting of the Philadelphia chapter was held on the 28th at the Engineer's Club, and a very interesting program of motion pictures was exhibited.

Mr. T. H. Nelson, Steel Works Manager of the Henry Disston & Sons Company, and Mr. W. S. Stephenson of the American Rolling Mill Company lectured, with movies showing the triplex process of the manufacture of ingot iron. The story of ingot iron was depicted very clearly with reels showing the methods used in the manufacture of pure iron and illustrated the latest approved methods of the manufacture of iron and steel.

To close the program a reel of comedy pictures were shown.

D. W. McDowell, reelected secretary-treasurer Pittsburgh Chapter.

J. E. Rogers, elected chairman of Worcester Chapter.

RHODE ISLAND CHAPTER

The May meeting of the Rhode Island Chapter was held on the 3rd of the month. A very interesting paper entitled "Inspection and Testing of Raw Materials and Heat Treated Parts for Automobiles to Insure Standing up in Service," was delivered by Mr. R. J. Allen, Metallurgist of the Rolls-Royce Company of America, Springfield, Mass. Mr. Allen who is vice president of the National Society, is an authority on steels and their proper heat treatment for use in the automotive industry. This paper was very well delivered and proved to be intensively interesting as evidenced by the large amount of discussion which followed.

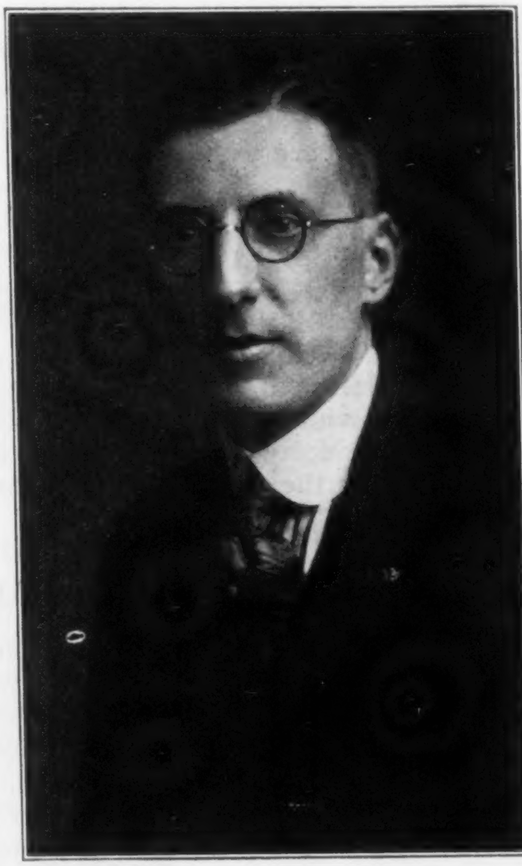
Mr. R. H. Schafer, Supt. of the Textile Finishing Machinery Com-

pany, Providence, was elected chairman, while Mr. F. H. Franklin, of Oleyville, R I. was elected vice-chairman for the coming year.

ST. LOUIS CHAPTER

The chapter held its May meeting on Friday evening, the 12th at the plant of the St. Louis Pressed Steel Company. The meeting consisted of an inspection trip through this plant. Mr. Key acted as guide

John E. Halbing, reelected chairman Lehigh Valley Chapter.



Albert P. Spooner, reelected secretary-treasurer Lehigh Valley Chapter.

and explained the main points of interest throughout his plant. Following this trip of inspection which proved very interesting and instructive, the chapter held a short meeting at which time the election of new officers took place.

SYRACUSE

The Syracuse chapter held its regular meeting May 5th at which time the officers for the ensuing year were elected. They are as follows: W. F. McNally, Chairman—New Process Gear Corporation, Syracuse; R. F. Smith, Vice-Chairman—E. F. Houghton Company, Syracuse; A. G. Carman, Secretary-Treasurer—H. H. Franklin Mfg. Company, Syracuse. The following executive committee officers were elected: H. J. Stagg—Halcomb Steel Company; S. C. Spalding—Halcomb Steel Company; Frank Singer—Syracuse Twist Drill Company; C. E. O'Connor—Sanderson Steel Company; Wallace Marriott— New Process Gear Corporation.

WORCESTER

The Worcester chapter held its annual banquet and meeting at the Boston Store restaurant on March 20. There were 95 present among whom were the leading executives of all of the metal working industries in Worcester.

The speakers for this meeting were our National President, F. P. Gilligan whose remarks were of a general nature; Dr. John A. Mathews who presented his paper on "Iron in Antiquity and Today"; Mr. N. R. O'Hara, humorist of the Boston Post, New York World, Life, and Judge, entertained the members for about 20 minutes with some very humorous sketches for which he has made a name throughout the country.

Following the speakers of the evening, the election of officers took place. They are as follows: J. E. Rogers, A. Hankey & Company, Rochdale, Chairman; W. A. Bacon, Reed-Prentice Company, Worcester, Secretary-Treasurer. The members of the executive committee are as follows: V. E. Hillman, Crompton & Knowles Loom Works, Worcester; George C. McCormick, Crompton & Knowles Loom Works; John C. Spence, Norton Co., Worcester; Philip Knowles, Walden-Worcester, Inc., Worcester, Mass.

Mr. Hillman in closing the year gave a very timely address on the advances which the Worcester Chapter had made and its prospects for the future. Many gratifying remarks were made to the members who were thanked for their enthusiasm in assisting with the work and purposes of the Society.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held its regular monthly meeting, May 29 at Easton Public Library at which time, Mr. B. H. Delong and Mr. R. W. Zimmerman delivered a paper entitled "Physical Testing." This paper was very instructive and was well received by those who were present.

ROCHESTER CHAPTER

On May 10th the Rochester Chapter held its regular monthly meeting. Mr. R. E. Talley of the Geo. J. Hagan Company delivered a very interesting paper entitled "Electric Furnaces for Heat Treating Purposes." As the electric furnace is coming into use more and more this topic proved of great interest to those who had the pleasure of hearing Mr. Talley.

DETROIT CHAPTER

The Detroit Chapter held its May meeting on the 8th in the Board of Commerce Building at which time Mr. Henry Voltmann of the W. S. Rockwell Company presented his paper entitled "Methods of Heating and Handling." Mr. Voltmann's paper contained very valuable information and was well received by the membership. His discussion of design and fuels were of prime interest.

The last meeting of the season for the Detroit Chapter was held on

May 22 in the Board of Commerce Rooms at 8 o'clock. The paper for this meeting was presented by Guy Baldwin of the Bruce Products Company entitled "Review of Metal Cleaning Process and Equipment". This paper was very interesting in that it dealt with the cleaning of metals prior to subsequent treatment.

The election and installation of officers was held at this meeting. They will be announced later.

BOSTON CHAPTER

Boston Chapter held its last meeting of the season on Friday, May 26th at the Boston City Club. The meeting was preceded by a dinner served at 6:45.

The annual meeting and election of officers was held after which the speaker of the evening, Mr. J. C. Spence of the Norton Company presented a very interesting paper entitled "Grinding Practice". Mr. Spence's paper was very instructive inasmuch as considerable difficulty is experienced in the production of hardened parts which are subsequently ground, resulting in grinding cracks. These cracks are usually due to the improper selection of grinding wheels. An interesting discussion following Mr. Spence's paper was held which revealed manv points of information to those present.

HARTFORD CHAPTER

The Hartford Chapter of the American Society for Steel Treating accepted the very kind invitation of Vice-President Hughes of the New Departure Manufacturing Co., to visit their plant at Bristol on the chapter's annual visitation trip Saturday, April 29.

The Hartford Chapter invited the New England chapters of the American Society for Steel Treating and also the New England sections of the Mechanical Engineers to visit with them. About 300 accepted and spent a very pleasant day at Bristol.

The guests began to arrive about 9 o'clock and were divided into groups of 15 to 20 and under the direction of guides from the New Departure staff, made a circuit of the entire plants, having the places of interest pointed out to them. A rather complete discription of this trip of inspection is given in the following pages. At the conclusion of this trip of inspection, the visitors partook of a buffet luncheon served in the cafe of the inn.

After the luncheon, the guests and members visited the Administration building and proceeded thence to the Endee Club where the program of the afternoon was conducted.

Mr. Marcus E. Gere, chairman of the Hartford Chapter welcomed the guests in the name of the Hartford Chapter and called upon Vice-President Hughes who extended a word of cordial welcome on behalf of the New Departure Co. Mr. Hughes outlined briefly, the history of the organization and the progress it had made in the last few years when it had grown from a small industry to one employing over a thirty million dollar capital; stating that the reason for the increase in growth was because

they had applied to their business, principles of honesty of purpose and honesty of execution.

Pres. Frank P. Gilligan of the National Society replied to Mr. Hughes' words of welcome and expressed appreciation for the many courtesies extended. Mr. Gilligan then served as chairman of the meeting and called

Members and guests of the Hartford Chapter who attended the trip of inspection meeting through the New Departure Mfg. Co's., plant at Bristol, Conn.

upon National Secretary, W. H. Eisenman to give a few remarks on "Heat Treating the Executive." The speaker brought out particularly the necessity for excellent working conditions, modern equipment and methods, so that progress would be made in the science of heat treatment.

The principal address of the afternoon was given by Prof. H. F. Moore of the University of Illinois, who presented his interesting and entertaining lecture on the "Fatigue of Metals," illustrating it with lantern slides and moving pictures. Prof. Moore's paper was exceptionally well received and proved a suitable climax to a most interesting day.

Before the meeting adjourned the following resolution was presented by Mr. Blackburn of the Hartford Chapter and unanimously adopted: "Resolved that all present extent to Vice President Hughes and his excellent staff of the New Department Mfg. Co., our hearty thanks for the many courtesies and the generous hospitality extended to us by our hosts.

That we especially convey our thanks to the committee of the New Departure Company consisting of Mr. C. B. Simmons, T. C. D. Crow and M. E. Gere, for the excellent arrangements for the reception and entertainment of us while at the plant and that we also extend our thanks to Mr. James J. Curran, L. A. Lanning and M. E. Gere, the committee of arrangements of the Hartford Chapter, for their efficient work in preparation of this notable event."

The New Departure Company gave as souvenirs to all those in attendance a 200-page booklet entitled "Ball Bearings in Industry" which had a two-page insert giving views of the plant the visitors had inspected. *The New Departure News* published by and for the employes of the New Departure Co., was placed in the hands of each member and especialy note-worthy was the editorial entitled "Our Guests Today" written by Mr. D. Page the editor in chief, which was as follows:

"Our guests today, members of the American Society for Steel Treat-

ing and American Society of Mechanical Engineers, will receive this copy of *The New Departure News* right from the press of our printing department. In its columns they will find reflected something of the New Departure spirit of industrial comradeship, loyalty, co-operation, and pride in both plant and product.

We extend a welcome to our guests in that same spirit and trust that their brief stay with us may prove to be not only interesting but helpful. It is a fine satisfaction to know that our work counts for constructive progress, that the results we attain are builded into development and improvement of invention and genius, that we are right-handed fellows, working each in his particular field, but all impelled by the same motive, to wit., establishing and maintaining world surpassing efficiency, principle, and method in American industry.

If there is one aim that is ahead of all others in the minds and work of New Departure employers and employes, it is this, that our product shall be unexcelled. The sincerity of that purpose you have undoubtedly sensed as you have passed through the plant and listened to what has been said concerning that which you have seen.

So our welcome is that of kind to kind, plus the cordiality and sincerity that is born of high respect for your organizations and your work as individuals."

TRIP OF INSPECTION THROUGH THE NEW DEPARTURE PLANT

The Forge plant was the first section visited. It is located nearly ½ of a mile from the main plant on one of the few comparatively flat lands in the vicinity of Bristol, adjacent to the railroad with which it has excellent connections. Our party arrived at the east end of the bar alley of the forge plant and viewed

Airplane view showing main office and works of the New Departure Mfg. Co. plant at Bristol, Conn.

the buildings on the right which are used for the general storage of material for consumption in the entire Bristol plant, where the material is received and unloaded from freight cars and stored. The forge shop proper is shown in Fig. 1. The bar shed which is 75 feet by 275 feet is of all steel construction equipped

with a crane for the unloading of bars direct from cars and facilities for storing and delivering the material to the forging operations in the shop across the way. The forge shop was especially designed under direction of the New Departure engineers and erected in 1919 and 1920. The building is 125 feet by 475 feet and is equipped with 35 large forging machines, many of them weighing upwards of eighty tons each. There are a few drop hammers used for the drop forgings of bicycle coaster brake parts and other similar work.

The forging operation is carried on by heating the bar in specially designed furnaces and upsetting it in dies by end-wise pressure, thus end-wise forging the bar which has hitherto been hotworked entirely in a longitudinal direction. A collar is raised up on the end of the bar in the fiirst operation, punched off in the second and the ring is completed. The steel used is electric furnace high carbon chrome steel, containing 1.05 per cent carbon and 1.65 per cent chromium, phosphorus and sulphur below 0.03 per cent. The buttends or tong holds remaining after the forging operation has been completed on large bars is carefully saved, reheated and rerolled into smaller sizes of bar in a three-high two-stand rolling mill. The hardening shop is arranged for the most efficient treatment of high alloy steels of high speed or similar nature used for the manufacture of dies. It was interesting to note the completeness of the installation and that all furnaces, with the exception of the two electric furnaces, were of New Departure design and construction.

Fig. 1—Forge Plant. The largest plant in the East using the upsetting type of forging machine.

In the die department dies are manufactured for use in the forge shop. The building is arranged in two heights, the smaller or belt machinery being grouped under the lower part and the heavier machinery in the higher part of the building. Great pains were taken to provide all facilities and the most modern sanitary arrangements for the convenience of the workmen.

The plant manager's offices were at the end of the building, while on the second floor the accounting and drafting departments were located. It is interesting to note that in the forge plant no artificial ventilation is required, there being sufficinet movable glass in the roof to be equivalent to the removal of half the roof.

MAIN PLANT

The party then followed the route of the forgings. Arriving at the main plant they entered the annealing building. The forgings are first normalized in the furnaces of a standard type. After normalizing the forgings are annealed in

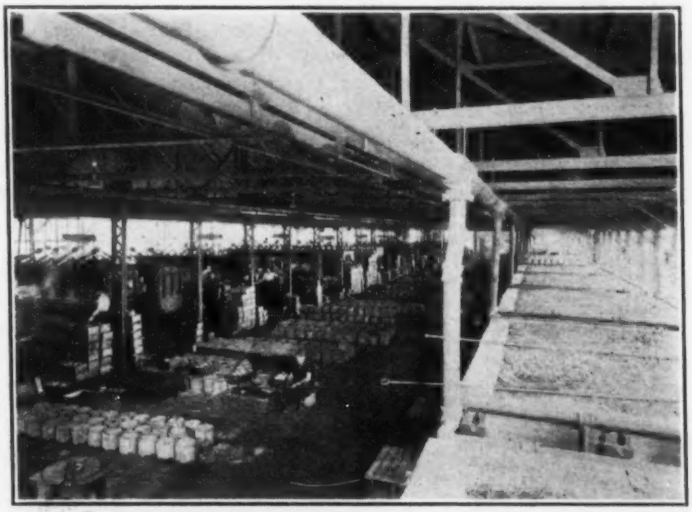


Fig. 2—Main Heat Treating Department. Plant A.

the 53 furnaces in this department. Two large pots containing forgings are loaded by the over-head crane. Each furnace charge consists of approximately two tons. The annealing of the high carbon chrome steel for proper metallurgi-

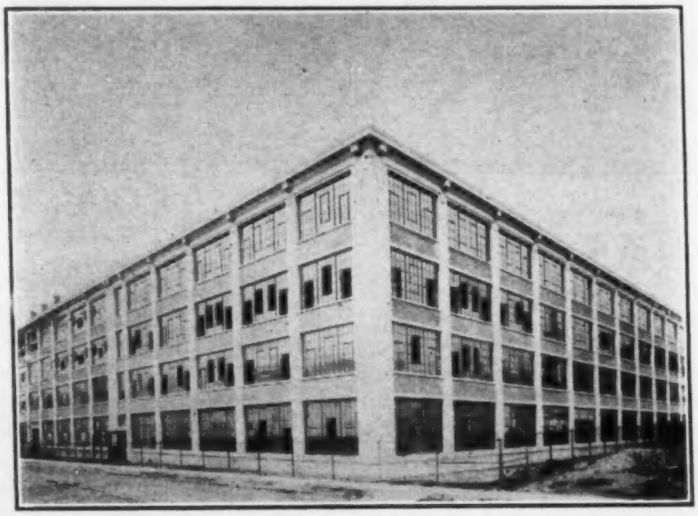


Fig. 3—Ball Plant. The largest steel ball plant in the world. Daily capacity 20,000 pounds of high carbon chrome steel balls, ranging in size from ⅛ to 2 inches in diameter.

cal properties requires the greatest care and the utmost accuracy in furnace design and control. In these furnaces from 100 to 150 tons of steel are constantly undergoing the annealing operation.

After annealing, the forgings are sent to be pickled in the pickling room.

Departing from the route of the forgings for a moment, the heat treating operations on the finished machined pieces was inspected. This department is shown in Fig. 2. In this building are the hardening and carburizing furnaces, all of New Departure design. The small loss of heat from these furnaces was due to the excellent insulation. The rings are strung on wires of which a standardized quantity is introduced into each furnace and heated for a standardized time in comparison with the pyrometer at the end, and then quenched in tanks of agitated quenching oil. The work to be quenched falls upon an oscillating grid by means of which it is automatically agitated and any possible chance of human laxity eliminated. The control of the furnace fire is not in the hands of the operator but is controlled by operating foreman called firemen who regulate furnace temperatures in accordance with what the pyrometer signals. The carburized work coming from the furnaces is handled mechanically and cooled in a shed on the left. After dumping, the empty pots travel to another building on the right and are repacked. Only coaster brake parts and certain parts of bearings are carburized, the vast majority of parts being made of hard high carbon steel.

Instead of the work being tempered in oil as heretofore, they have worked out a novel application of electric heat in the tempering oven. The work to be tempered travels back and forth through the oven the tempering being effected by heated air, automatically circulated and automatically, pryometically

Fig. 4—Interior of Semi-Final Grinding Department. Plant A.

and electrically controlled. The maximum variation from fixed temperatures in any part of the furnace does not exceed three degrees.

The testing laboratory occupies the whole front of a building of three floors. The chemical laboratory is arranged for the most economical handling of their particular problems while the metallurgical laboratory is provided with all the usual and some unusual equipment.

Some years ago New Departure engineers and metallurgists developed a process by which high carbon chrome tool steel can be so treated as to be made into the strongest possible ball by a cold forging process. This entails an enormous outlay for annealing and treating plants, as well as a wire mill, and upon these prior operations the greatest of care is expended. This building which is under construction will be largely a duplicate of the annealing building just described, adapted for the annealing of large sized wire and rods. After annealing of the wire which is done in the presence of carbonaceous material to prevent decarbonization, soft spots and reduce scale, it is pickled in concrete pickling tanks. The wire is then pointed so that it may enter the drawing dies. In these machines pointed wire is inserted and reduced by be-

ing drawn through dies. After drawng, the wire is suitably stiffened and is re-annealed to make ready for the grinding operation. The ground floor of this building is interesting in that it contains considerably over two acres, is 220′ wide x 460′ long and the entire ball plant contains in one building considerably over six acres of floor space.

The fourth floor which covers over an acre in extent is devoted to rough

Fig. 5—Endee Inn. Hotel-Club for employees.

grinding. The machines are continuous and automatic. The balls, in lots, as they come from the first operation proceed through all succeeding operations in lots of approximately 250 pounds each. The grinding is done by means of an abrasive wheel, balls in a stream passing over the face of this wheel are

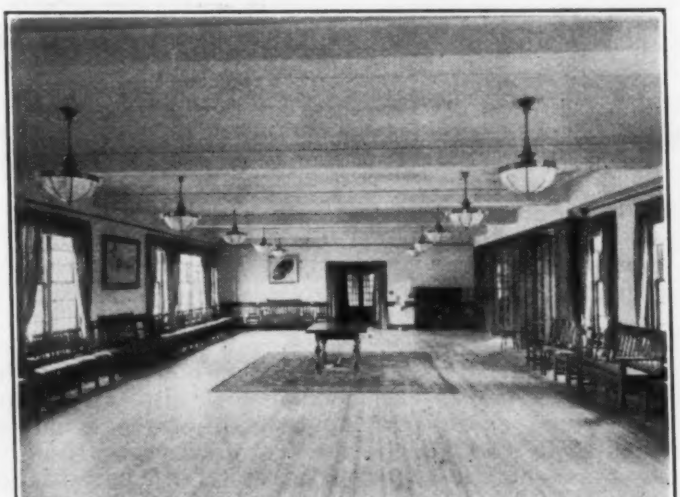


Fig. 6—Assembly Hall, Endee Club.

ground in the soft state to within a few thousand of finished size. After the rough grinding, balls are normalized and annealed and then hardened. At the present time the hardening shop is on the 4th floor, but is about to be moved

adjacent to the large building. The balls are hardened on flat trays two or four trays to a furnace and quenched in these very deep tanks extending to the floor below.

The finish grinding floor is still in process of reconstruction. It contains upwards of an acre and a half of floor space. Here the hardened balls are lapped continuously and automatically between grooved iron plates between which a thin abrasive compound is passed. After grinding they are wiped with sawdust and fine leather to remove all traces of abrasive in tumbling barrels on the right. On the second floor all balls are given inspection for service perfection. Each perfect ball passes through the hands of five consecutive inspectors and arrives at the perfect grade through the process of elimination of all imperfections. Perfect balls are here gaged for size to ten thousandths of an inch and sorted into containers all balls in which are maintained to within a limit of one ten thousandth of an inch. Throughout the process and continuously the balls are checked for spheroidty. The limit is an eighth of a ten thousandth of an inch.

The ball plant shown in Fig. 3 is one of the largest if not the largest in the world, containing over six acres of floor space. It has a production of

Fig. 7—The Lounge, Endee Club.

20,000 pounds daily. All sizes are made from ⅛ inch to 2 inches in diameter.

The party then followed the hardened race-rings into the semi-final grinding department, shown in Fig 4. This building is 130 feet wide and approximately 300 feet long given over to the grinding operations on the race rings as parts before the introduction of the balls and the assembly of the bearing. The first operation is surface grinding, then internal grinding, then oscillation of race groove. Inner races are bore ground. Every operation is followed by inspection to the highest accuracy conceivable. A large shop is given over solely to the manufacture of gages.

The Endee Inn, shown in Fig. 5, Fig. 6 and Fig. 7 is an employee's hotel built to house 314 men and as assistance to the housing facilities to meet the company's operations in Bristol. The company is also an extensive builder of houses and owns in whole or in part upwards of seven hundred houses which it has been instrumental in erecting in the last few years.

In three factories the company employs a capital of upwards of $30,000,000.00 and in normal operating times they have ten thousand employees with a daily production capacity of 60,000 bearings and 3000 coaster brakes. Two other plants are maintained, one at Hartford for manufacture of small bearings with a capacity of 20,000 bearings per day. A new plant has recently been erected in Meriden, Conn., destined to have a productive capacity of 20,000 bearings per day. At this plant in Bristol another 20,000 bearings a day can be produced, as well as all the forging, the major part of the heat treating and all the ball manufacture.

Commercial Items of Interest

UNITED States Civil Service Commission, Washington, D. C. announces open competitive examinations for Federal civil service in which many chemists, metallurgists and heat treaters will be particularly interested. The positions which are now open and for which these examinations will be given shortly are, Laboratorian—Chemical, Physical and Engineering; Laboratory Assistant—Junior Grade, $1000.00 a year and Senior Aid $900.00 a year. Those interested in these examinations may obtain full information regarding them from the Civil Service Commission, Washington, D. C., or the secretary of the civil service board at the post office or custom house in any city.

Howard E. Handy, formerly Assistant Metallurgical Superintendent of the Washington Steel & Ordnance Company has been appointed Metallurgist for the Saco-Lowell Shops, Manufacturers of Textile Machinery, at Lowell, Mass. Prior to going to Washington, Mr. Handy was associated with the American Locomotive Company as Assistant Engineer of Tests.

The Fahy Experimental Permeameter developed by Frank P. Fahy is described in bulletin 990 published by James G. Biddle, of Philadelphia. This bulletin discusses magnetic measurement, going into more or less detail on the physical aspects of the subject describing in some detail on the on the physical aspects of the subject describing in some detail various physical terms. It then discusses the Fahy Experimental Permeameter and its application to the tests of materials for their magnetic properties.

The Detroit Twist Drill Company has inaugurated a technical service department which is compiling valuable information for the engineer. This information is being distributed in bulletin form on standard 8½ x 11 loose leaf note book paper, which makes it possible to be inserted in a loose leaf binder for ready reference. These bulletins cover such items as the discussion of the advantages of ground wire drills; the modern high speed drill and the Detroit expansion hand reamer; the taper bridge reamer, etc. Each of the topics are illustrated and handled in a very comprehensive manner including considerable detail of design and method of manufacture.

The Iron and Steel Institute held its annual meeting Thursday and Friday, May 4th and 5th, 1922 in London, England. A very interesting program had been arranged covering some very valuable new information covering recent researches in iron and steel.

The Metal & Thermit Corporation, 120 Broadway, New York City announces the removal of its Pittsburgh branch office from 1427 Western Avenue to 801-807 Hillsboro Street, Corliss Station, Pittsburgh, Pa.

(*Continued on Page* 34)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

METALLURGIST or SUPT. HEAT TREATING—Technical graduate University of Illinois. Experience in heat treating and annealing forgings and castings all sizes up to 50 tons; production study and estimating; metallurgy, metallography, chemical analysis; physical testing and final inspection; installation and maintenance various makes pyrometers; research and investigation; three years superintendent heat treating. Age 30. Address 4-12.

METALLURGIST—or Supt. of Heat Treating with 12 years experience, 10 of which have been as executive in charge of laboratories and supervisor of metallurgical operations in Steel Works and industrial plants. Broad experience in chemical, physical and metallographical testing and the heat treatment of automobile and other alloy steels. Location desired East of Pittsburg, age 30, married. Address 4-7

SUPERVISOR HEAT TREATING, Chemical, Metallurgical Metallographical Laboratory large Motor Truck Company. 12 years experience. Formerly with U S. Steel Corporation, U. S. Government Engineer of Tests & Metallurgist, also foundry experience in malleable, gray iron, steel, semi-steel. Age 35. American. Married. Eastern location preferred. Wages desired $200.00 per month. Answer 3-25.

ENGINEERING or PRODUCTION WORK—Technical Graduate. 2 years heat treatment of armor plate, guns, etc. 2 years charge heat treatment auto parts. 2 years charge commercial heat treating shop. At present employed as equipment sales agent. Desire to make change to engineering or production work. Salary desired $200-$250. per month. Address 5-25.

SALESMAN—Graduate University of Pittsburgh. 3 years chemist. 3½ years chemist and metallurgist. 3½ metallurgist and chief inspector. Experience in all departments of mill work, rods, wire, plates, spikes, etc. Familiar with nearly all classes of steels including alloys. Location preferred Pittsburgh. Address 5-30.

METALLURGIST—10 years experience in carburizing and heat treatment of carbon, alloy and tool steels. Extensive experience in physical testing, metallography, pyrometry and metallurgical research. Also experienced in handling large forces of men. Have had as many as 600 men under my supervision. Eastern location preferred. Salary desired $4500. per year. Address 5-35.

SUPERVISOR HEAT TREATING—Or assistant Ten years experience as chemist on iron and steel. One year practical experience on metallurgical inspection directly connected with heat treatment. Have made a study of the subject. No preference as to location. Wages $40.00 per week desired. Answer 5-50.

FURNACE DESIGNER and BUILDER—Steel treating furnaces or to take charge of furnace construction and repairs in steel treating department of large manufacturing plant. A number of years experience designing, building and operating furnaces of all types for all classes of work including mechanical and automatic furnaces for heat-treating, carbonizing, and annealing. Willing to make part of compensation dependent upon ability to improve quality of work and reduce costs. Location immaterial. Address 5-5.

ASSISTANT METALLURGIST—4½ years experience in U. S. Armories, 4 years laboratories brass rolling mill and shell factory. Experience included installation and maintenance pyrometers, research work, micro examinations and microphotography, critical temperature measurements and carburizing and heat treatment of small parts. Willing to consider any position in metallurgical department, annealing or heat treating department providing there is opportunity for advancement. Wages desired $150.00 per month. Location preferred Rhode Island, Massachusetts, or Connecticut. Address 5-15.

METALLURGIST AND ENGINEER—Experience in purchasing, production, layout, forge shop, heat treating, laboratory and research work. Capable of taking entire charge of malleable, gray iron, semi steel or steel foundry. Desires employment with progressive firm. Address 5-41.

CHEMIST—Metallurgist, metallographist, physical tester or heat treater. 12 years experience. Former Government metallurgist. Now an executive with large motor truck company. Also malleable and semi-steel foundry experience. Can organize and manage men. No location preferred. Address 5-10.

SALES ENGINEER—Thorough metallurgical training and experienced salesman. At present employed but desires change. Wide acquaintance New York, New England and Canada. Basic knowledge foreign markets and can produce. Age 28. Married. Address 4-5.

METALLURGIST OR CHEMIST—Graduate of Ohio State. Extensive experience covering heat treatment, case hardening, pyrometry, chemical analysis, metallography, and investigation of tool troubles. Best of recommendations. No preference as to location. Address: 4-50.

Was connected with United States Naval Ordnance Plant having charge of metallography and heat treatment the past two years, has had practical electric melting experience. Best of recommendations. No restrictions of location. Address 4-35.

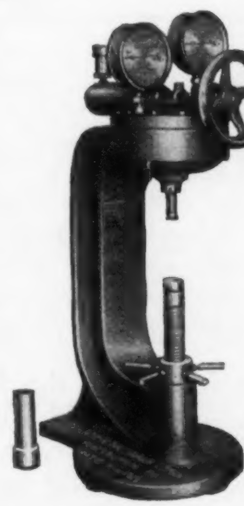
HEAT TREATING DEPARTMENT—Technical graduate. Hardening room automobile firm. Experienced on aluminum castings. Die Superintendent and metallurgist for steel tool company. Salary $150.00. Cleveland location preferred. Address 4-10.

(Continued on Page 34, Adv. Sec.)

Temperature

With the **F. and F. Optical Pyrometer** the temperature is measured by merely observing the object. It is accurate, simple and substantial.

(Write for Booklet)



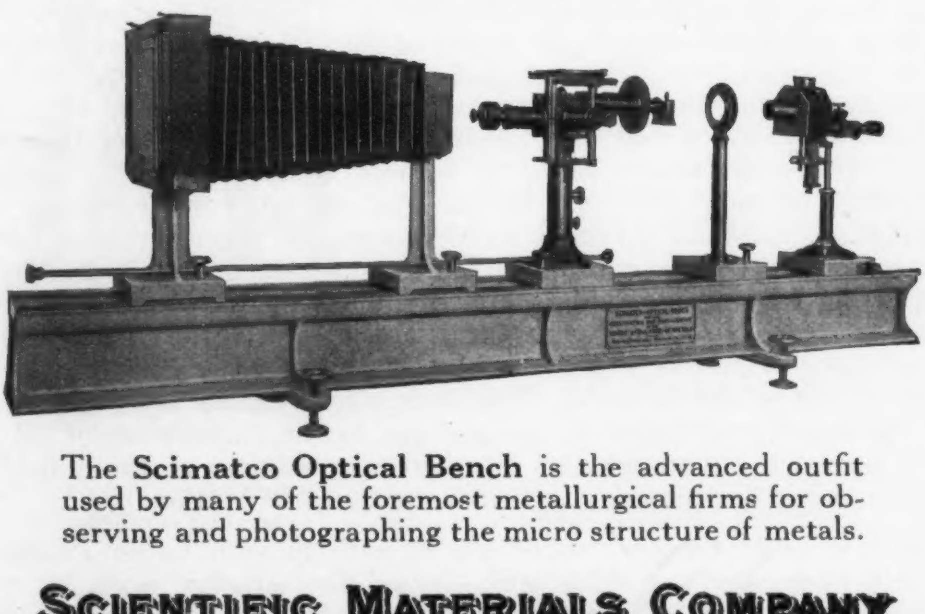
Hardness

The **S. M. Co. Brinell Machine** is the standard machine for measuring hardness of metals adopted by more than 100 leading concerns.

Pressure is applied quickly and uniformly; a special feature prevents leakage of the hydraulic fluid.

(Ask for Booklet on Hardness Tests)

Micro-Structure



The **Scimatco Optical Bench** is the advanced outfit used by many of the foremost metallurgical firms for observing and photographing the micro structure of metals.

SCIENTIFIC MATERIALS COMPANY

"Everything for the Laboratory"

PITTSBURGH, PA.

EMPLOYMENT SERVICE BUREAU

(*Continued from Page 846*)

POSITION WANTED

SUPERINTENDENT OF HEAT TREATING—7 years experience heat treating of carbon, highspeed and other alloy steels. Experience in metallographic testing Understands pyrometry. Techincal education. Best of references. Location desired, Chicago or near vicinity. Address 6-15.

SERVICE MAN—for steel company. Experience in heat treatment of carbon, high speed and alloy steels, also metallographic testing and pyrometry. Technical education. Best references. Address 6-20.

FOR SALE

Leeds & Northrup, Hump Method, Electric Furnace for sale. Used very little. Address 6-1.

POSITIONS OPEN

WANTED—Young college graduate with one or two years practical experience in physical metallurgy to carry out physical tests and micro examination with a government bureau. Entrance salary $1800 per annum. Position offers excellent opportunity to become familiar with certain phases of physical metallurgy of great practical value. Address 4-32.

WANTED—Practical Superintendent for tool stee wire and shape drawing department. Reply box 6-5 care American Society for Steel Treating.

(*Continued from Page* 845)

The Geo. J. Hagan Company have recently been awarded a third contract from the Nash Motors Company, Kenosha, Wisconsin for a large rotary furnace, electrically heated and of 150 KW capacity.

The American Supply Company, 135 Washington Street, Providence, Rhode Island has been appointed agent for the Providence district to represent the Quigley Furnace Specialties Company of New York, Manufacturers of Hytempite. The Quigley products are warehoused in Providence for quick delivery to local points.

On May first, the Bristol Company opened a new branch office at Philadelphia, Room 1311, Widener Building. Mr. C. C. Eagle, Jr., salesman and service engineer, is in charge. Mr. Eagle is a man who has had broad experience, including both laboratory training at the factory and sales experience in the field, and was formerly in charge of their Detroit Office.

The surface combustion low pressure air-gas inspirator, for many years used exclusively on the Surface Combustion Company's furnaces, has recently been redesigned so as to be readily applied to any make of gas furnace.

The manufacturers, The Surface Combustion Company, Inc., industrial furnace engineers and manufacturers, 366-368 Gerard Ave., Bronx, New York City, claim that this inspirator is essentially a gas furnace carburetor. The entire operation of a furnace equipped with this inspirator is controlled through only one valve. An increase or decrease of the air supply automatically increases or decreases the gas so that the mixture proportions remain in a constant fixed ratio. The gas cock is used only when starting or stopping and is either full on or full off; no adjustment of it is required. No explosive mixtures are possible in any part of the distribution mains with this system, as the gas and air are mixed only at the point of supply to the burners. The advantages claimed are automatic supply of the exact proportions of air and gas to the furnace under all conditions of operation; thorough and homogeneous mixing of these fluids just prior to entering the furnace; and instantaneous combustion.

The first large freighter to be loaded entirely with Celite Products recently left Port San Luis, California, bound for Atlantic ports by way of the Panama Canal. A second freighter is now receiving its cargo, and this will be followed by still another boat also devoted exclusively to their materials.

Although the Celite Products Company have made water shipments

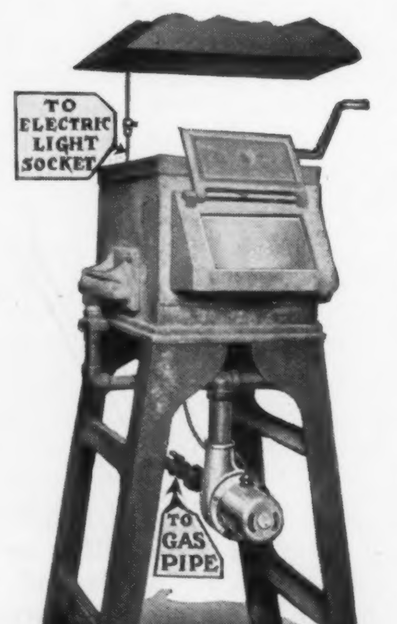
(*Continued on Page* 36)

CADILLAC

ELECTRIC FURNACE

BLAST

A Forward Step in Heat Treating



Heating Furnace Equipped with CADILLAC ELECTRIC FURNACE BLAST.

Connects with electric light socket.

Ready for business any time—day or night. Not dependent upon power from line shaft.

Maintains uniformity in heating temperature.

Makes it possible to operate furnaces individually, adapting each to the special requirements of the job.

May be used on small or large furnaces; has very wide range of application.

May be installed as an auxiliary to be coupled up to a given furnace on special occasions when necessary to secure a sustained high non-varying temperature.

Economically operated by 1/6th H.P. motoı.

Equipped with fittings ready to install.

Send for price and descriptive folder

CLEMENTS MFG. CO.

607 Fulton St. CHICAGO

(*Continued from Page* 34)

quite frequently in the past to the Atlantic coast, this is the first time that three entire vessels have been used to the exclusion of other cargoes. Loaded to capacity, these ships mark a departure from their established transportation method which will undoubtedly be repeated at frequent intervals.

In order to handle their materials in this manner, it is necessary to ship by automobile truck from the producing point at Lompoc to Harris Station on the Pacific Coast R. R. The railroad carries from this point directly to the loading wharves. Despite two short hauls and rehandling, the Celite Products Company find that this method of water shipment reduces the final cost to consumer to an appreciable extent. It enables them to give large users the full advantage of gross shipment and decreases the transportation charge on stock maintained in Eastern warehouses.

A chapter of the Society of Industrial Engineers was recently organized among students at Carnegie Institute of Technology, Pittsburgh, to be known as the Carnegie Industrial Engineers Society. This is the third chapter to be organized in the country.

The Department of Machine Construction, under Professor Charles C. Leeds, the head, organized the chapter which includes 108 members. All sophomores, juniors, and seniors taking four year degree courses in the Colleges of Engineering, and of Industries are eligible, but a satisfactory scholastic standing must be maintained to hold membership.

Professor Joseph W. Roe, of New York University, and President of the Society of Industrial Engineers, was present at the initiation and spoke to the members. Dr. A. A. Hamerschlag, President of Carnegie Tech, also gave an address and was made Honorary Chairman.

The officers are: President R. W. Marshall, of Pittsburgh; Vice President, J. V. Foster, of Latrobe, Pa.; Secretary, J. K. Matter, of Harrisburg, Pa.; Treasurer, B. N. Greenlaw, of Ridgewood, N. J.

Four hundred engineers from all parts of the Valley participated in the business meeting and election of officers of the Engineers' Club, and afterward heard Dean Cooley give a stirring address on the duties and work of engineers and the vital need of organized action by engineers to keep the country on the upgrade during and after the present period of reconstruction. The meeting was held at Drown Hall, Lehigh University on Monday evening, May 8.

Dr. Emery, Vice President of Lehigh University, in introducing Mr. Mortimer Cooley, Dean of the Colleges of Engineering and Architecture of the University of Michigan, referred to his long list of degrees and honors. Dean Cooley is a graduate of the U. S. Naval Academy at Annapolis and has been teaching engineering for many years. He has been president of the Society for the Promotion of Engineering Education, and also president of the American Society of Mechanical Engineers. He is now President of the Council of the Federated American Engineering Societies, the head and spokesman for a society including nearly 60,000 engineers. Dean Cooley is successor in this position to Herbert Hoover, also an engineer, who was the first President of the Federated American Engineering

(*Continued on Page* 38)

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Societies and who served till his appointment as a member of President Harding's Cabinet.

After referring to his recent trip through the Southwestern States in which he visited the engineering societies and the universities, Dean Cooley contrasted the engineer with the members of the other professions. The engineer suffers in that, while the lawyer, the doctor, and the clergymen come into direct personal contact with the public, the engineer speaks only through his work. To increase the effectiveness of his service he must secure direct contact with the world by engaging in the solution of problems when they are in the stage of general discussion and enlist the popular interest.

Dean Cooley spoke of the general acceptance of the Federated American Engineering Societies as an organization not animated by any selfish interest, and referred to the enormous influence it will have when it grows to 200,000 members and includes all of the members of engineering societies in America.

A striking thought brought out by the speaker was that, while the World War was due to the clash for commercial supremacy, and while the war was fought by the engineer and won by the engineer, he is little thought of now that the war is over.

After referring to the organization of the Engineering Council which includes one member for each 1000 members of the federated societies, Mr. Cooley referred to the work of the Council in pushing through Prindle's reorganization of the patent office and in investigations of industrial waste and industrial depression. Mr. Cooley showed that the loss of our foreign trade in manufactured articles would account for our present industrial depression. Recently the President and Congressmen were presented with good German watches costing from 80 cents to $1.33. Germany can make 1000 per cent profit on many manufactured articles and still undersell us in South America. We can only compete by eliminating all waste in industrial operations. Among other illustrations consider freight traffic on the railroad. On the average, in the whole United States, each freight car carries a load 12 miles each day. If we can make a freight car run 24 miles a day with a load, the problem of reduced freight rates is solved.

The present and future work of the Federation includes study and planning for elimination of waste in industry and agriculture, study of land and water transportation, investigation of public utilities, foreign trade, engineering education and reforestation.

Mr. Cooley urged the Engineers' Club to take an organized and active interest in all public improvements, pointing out that to secure progress without lost motion the engineer must educate and lead the public.

The Chicago branch of the Driver-Harris Co., manufacturers of Nichrome heat treating containers, has taken enlarged quarters and will be located in them after May 1. These new quarters are at 562-574 West Randolph street.

K. W. Zimmershied has been appointed to assist P. S. DuPont, president of the General Motors Corporation.

Wilson-Maeulen Co., Inc., New York, has published a 20-

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page illustrated booklet in which pyrometers, pyrometer recorders, etc., are described and illustrated. A multirecord, multicolor pyrometer recorder is included in the equipment described. This operates with base metal or rare metal thermocouples in thermoelectric pyrometer service. It also operates as a low temperature recorder or electrical resistance thermometer in connection with resistance thermometer bulbs. Full details are given in the booklet, which also includes descriptions of parts, accessories, etc.

Judge Learned Hand of the U. S. District Court, Southern District of New York, rendered Thursday, April 13, a decision on the rustless and stainless iron and steel patents of the American Stainless Steel Co. in the latter's case against the Ludlum Steel Co., Watervliet, N. Y., for infringement. The bill was dismissed for non-infringement.

The Ludlum company has patents covering chrome-silicon alloy steels, while the Brearley and Haynes patents cover stainless steels having a high chromium content. The decision apparently hinged on the silicon content of the Ludlum steels. "The issue," says the decision, "is whether the addition of silicon, which obviates the necessary additional heating of the plaintiff's composition beyond its critical point, makes the resulting article an infringement. Obviously this could not be. * * * Granting that the addition of silicon would not avoid infringement, it does not create it."

Wells K. Gregg, chairman of Milwaukee Chapter has resigned his position as metallurgist with the Cutler-Hammer Co., and has accepted a position with the Superior Charcoal Iron Co. Mr. Gregg's headquarters will be at Grand Rapids, Michigan.

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